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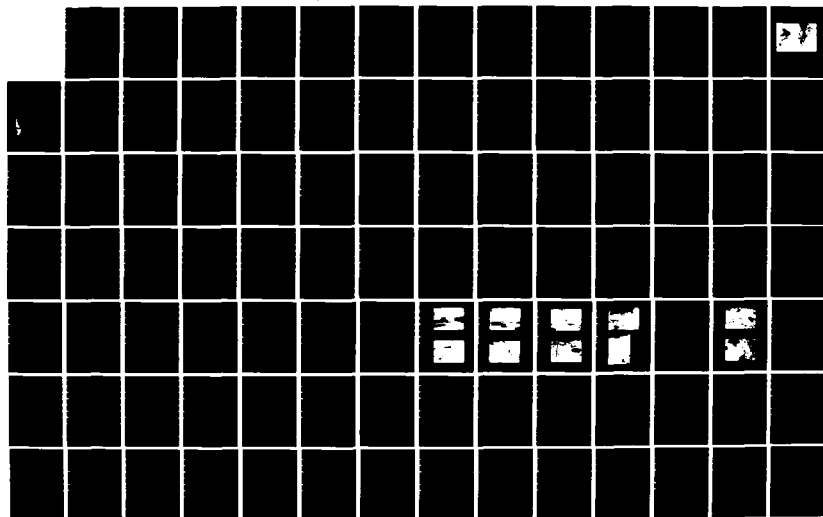
NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS
WOODWARD RESERVOIR DA. (U) CORPS OF ENGINEERS WALTHAM
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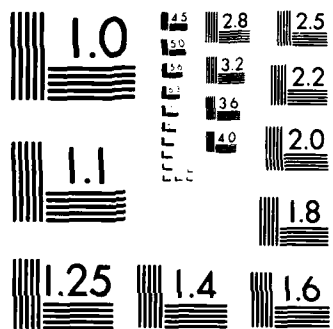
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WOODWARD Reservoir DAM

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CONNECTICUT RIVER BASIN
PLYMOUTH, VERMONT

WOODWARD RESERVOIR DAM
V T. 00209

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS. 02154

MAY 1979

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The dam is a stone earth fill dam with a concrete emergency spillway. The dam is about 150 ft. long with a maximum height of 30 ft. It is intermediate in size with a significant hazard potential. There were few significant conditions which should be corrected by the owner. The dam should be continuously monitored during high flows and the gate opened as necessary to minimize flows over the spillway.		

WOODWARD RESERVOIR DAM

VT 00209

PLYMOUTH, VERMONT

PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM

NATIONAL DAM INSPECTION PROGRAM

PHASE I INSPECTION REPORT

Identification No: VT 00209
Name of Dam: Woodward Reservoir
Town: Plymouth
County and State: Windsor County, Vermont
Stream: Reservoir Brook
Date of Inspection: April 23, 1979

BRIEF ASSESSMENT

The Woodward Reservoir Dam is a stone-earth fill dam with a concrete emergency spillway. The dam is approximately 150 feet long with a maximum height of 30 feet and a crest width of 48 feet. The downstream face is vertical, made of stone; while the upstream face has a slope of approximately 1 on 2 with a concrete slab along the top of the slope for embankment protection. The dam and impoundment are part of The Farm and Wilderness Camps, used solely for recreation. The reservoir surface area is approximately 101 acres while the drainage area comprises 2.87 square miles.

The gate house located immediately ahead of the concrete spillway provides control of a 2-foot by 2-foot stone box low-level outlet.

Based on intermediate size and significant hazard classification, in accordance with "Recommended Guidelines for Safety Inspection of Dams, Department of the Army, November 1976," the test flood for this dam is one-half the probable maximum flood (PMF). The test flood inflow was found to be 4732 CFS (1649 CSM) which after routing is reduced to an outflow of 2554 CFS (890 CSM). The routed test flood outflow based on no stop logs in place overtops the embankment by approximately 2.8 feet. The combined low-level outlet and spillway capacity, without embankment overtopping, is 564 CFS which is 22 percent of the test flood.

The following significant conditions were observed:

1. Erosion has occurred at both upstream abutments and sloughing of the impoundment shoreline has started.
2. Small trees have been allowed to grow from the masonry on the downstream face.
3. An area of leakage estimated at 7 to 8 GPM was found downstream of the left abutment.
4. The downstream vertical face of the spillway is in very poor condition. Severe spalling for the full height has exposed the reinforcing.

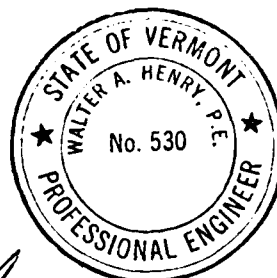
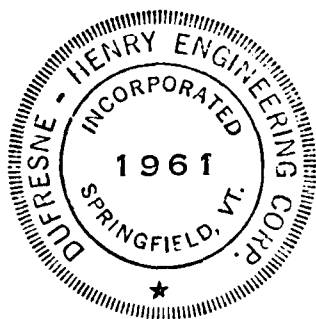
5. Erosion at the downstream toe of the dam has undermined the outlet conduit.

The Woodward Reservoir Dam is in poor condition and subject to continued deterioration when water flows through the spillway. A detailed assessment and recommendations for remedial action are contained in Section 7 of this report. In summary, it is recommended that the following actions be instituted under the guidance of a qualified engineer within one year of the receipt of this report:

1. Design plans to repair the undermining at the toe of the spillway and to prevent future undermining.
2. Design and reconstruction of the downstream face of the spillway and the training walls.
3. Assess the spillway capacity.
4. Prepare a formal warning system.

In addition the dam should be continuously monitored during high flows and the gate opened as necessary to minimize flows over the spillway. Normal lake level should be lowered until the recommended repairs can be accomplished.

Following the repairs listed above, institute an annual safety technical inspection program, to include monitoring the seep to the left of the spillway.



Walter A. Henry

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testing and detailed computational evaluations are beyond the scope of a Phase I Investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Spillway Test Flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the test flood should not be interpreted as necessarily posing a highly inadequate condition. The test flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

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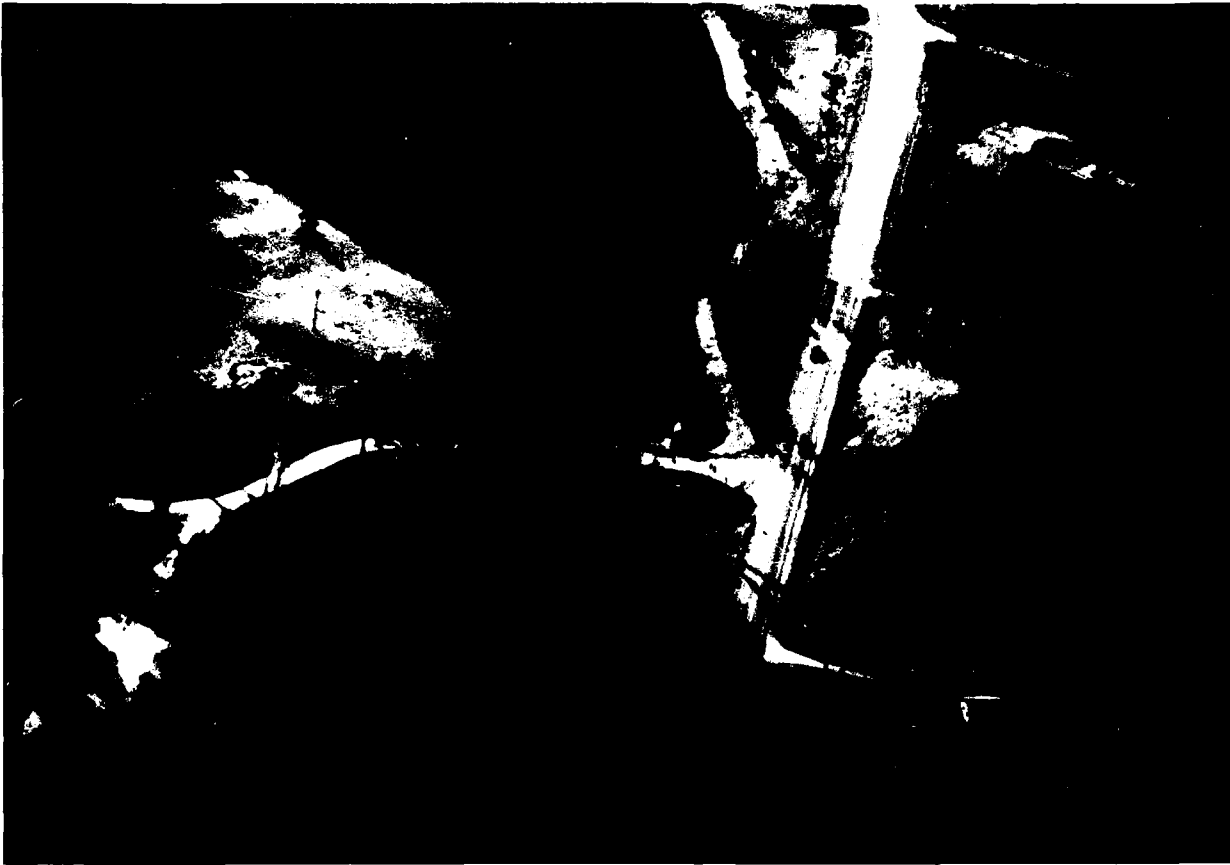
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OVERVIEW OF
WOODWARD RESERVOIR DAM
PLYMOUTH, VERMONT

f. Dam Failure Analysis

In the event the Woodward Reservoir Dam failed with the water elevation level at the top of the dam an initial wave of approximately 20 feet high would be released. The discharge would be approximately 10,500 CFS. Due to the steep mountain side slopes, this wave would continue down the valley. Approximately 1200 feet downstream Route 100 would be overtopped by 2 feet of water, surcharging the culvert there, and because of the steep channel gradient, this section of highway would be destroyed. About 5200 feet downstream of the dam, a house which sits on the bank of the Reservoir Brook, 11 feet above the streambed, would be undermined and destroyed. Further downstream, approximately 6200 feet from the dam, five or six homes are situated in a field near the brook. At this point the water would be 2 feet deep surrounding the homes, two of which are approximately 14 feet above the streambed. Thus much damage and possible loss of lives would result if the Woodward Reservoir Dam failed.

SECTION 5 - HYDRAULIC AND HYDROLOGIC EVALUATION

5.1 Evaluation of Features

a. General

The Woodward Reservoir Dam is an earth fill masonry dam with a concrete spillway which acts as a broad crested weir. The impoundment is used solely for recreation.

b. Design Data

There is no existing design data available for this dam. The hydraulic/hydrologic calculations were based on field measurements.

c. Experience Data

There are no records available for Woodward Reservoir. However, according to the Plant Manager, Bruce Nelson, the dam was slightly overtopped during the 1973 flood. Water during the June-July 1973 flood flowed over the dam at each of the abutments.

d. Visual Observation

The visual inspection of the dam revealed erosion at both right and left upstream abutments, caused by the 1973 flood. Also observed was the severely scoured downstream face, with only remnants for training walls. One major seep was found on the downstream left abutment approximately 3 feet higher in elevation than the low-level outlet. This leakage was believed to be coming either through the mass of the dam or around the entire abutment.

e. Test Flood Analysis

Based on a size classification of intermediate and a hazard classification of significant, the test flood was selected to be one-half the probable maximum flood (1/2 PMF). The test flood was developed using the computer program HEC-1 from the U. S. Army Corps of Engineers. The peak inflow was found to be 4732 CFS (1649 CSM) and after routing through surcharge storage, the routed test flood outflow is 2554 CFS. During the test flood the Woodward Reservoir Dam would be overtopped by approximately 2.8 feet of water, assuming that the spillway stop logs were not in place and that neither the left abutment nor Route 100 were eroded first. The combined capacity of the low-level outlet and the spillway is 564 CFS which is 22 percent of the test flood.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 Procedures

The established operational procedures for the Woodward Reservoir Dam consist of regulation of the water level. In the fall the level is lowered by opening the low-level outlet, and in the spring the level is allowed to rise and is maintained throughout the summer by the placement of stop logs.

4.2 Maintenance of Dam

There is no maintenance being performed on this dam.

4.3 Maintenance of Operating Facilities

The maintenance of the operating facilities consists of periodic inspection, operation and necessary repair of the gate and gate house controlling the low-level outlet. According to the Plant Manager, Bruce Nelson, the valve stem had to be repaired in April of 1978.

4.4 Description of Warning System

None exists for the Woodward Reservoir Dam

4.5 Evaluation

The maintenance of the gate house and valve is adequate. The maintenance program should be extended to include the clearing of brush and a few trees immediately downstream of the dam.

In addition, a plan for spillway and low-level outlet flow control should be initiated and maintained during periods of flooding and heavy rains.

spillway is in very poor condition. As Photo 8 indicates, the concrete facing has been completely scoured, exposing reinforcing rods and large cobbles which were used as aggregate. The photograph also shows the remains of two training walls which have been completely worn away.

Upstream of the spillway sits a gate house elevated above the spillway floor slab by two concrete supporting walls (Photo 3). The gate house provides control of a 2-foot square stone low-level outlet. According to the Plant Manager, the low-level outlet has a log bar screen on the intake. The inlet was under water and not visible during the inspection. The gate is in good working condition and was operated easily during the inspection. The stem had to be repaired in April of 1978. The downstream end of the low-level outlet has been severely scoured (see Photo 6) and with the added effect from the emergency spillway directly above, has started to undermine the dam.

d. Reservoir Area

The reservoir area consists of approximately 101 acres and is used solely for recreational purposes. The upstream banks have trees growing on them with roots being exposed, indicating slight sloughing of the banks. Some sedimentation has occurred directly upstream of the dam.

e. Downstream Channel

The channel downstream of the Woodward Reservoir is a natural streambed. Several trees have grown immediately downstream of the dam, and some debris has collected. The remainder of the channel is very rough filled with many boulders (see Photo 7).

3.2 Evaluation

The dam was found to be in poor condition based on the visual inspection. Some erosion and sloughing have occurred on the upstream abutments. The gate house and service gate are in good condition. However, the downstream spillway face has completely deteriorated including the training walls. Further deterioration is likely to continue when water flows through the spillway. Along with the scouring effect, undermining of the dam has started and is endangering the stability of the dam. A seep of 7 to 8 GPM was discovered at the left abutment, thought to be flowing through the dam. The trees growing on the downstream masonry wall can accelerate deterioration of the wall.

SECTION 3 - VISUAL INSPECTION

3.1 Findings

a. General

The Woodward Reservoir Dam is judged to be in poor condition based on the visual inspection. The downstream face of the emergency spillway has scoured badly and leakage was found near the left abutment.

b. Dam

The dam is an earth fill stone masonry dam located on the northern end of the reservoir adjacent to Route 100. The dam is approximately 150 feet long with a top width of 48 feet and a maximum height of 30 feet. The upstream face of the dam is protected by a concrete slab and concrete wall as shown in Photos 1 and 2.

The condition of the concrete is fair with spalling occurring particularly at construction joints. Some erosion has occurred at the left and right abutments as shown in Photos 1 and 5. According to the Plant Manager, Bruce Nelson, this happened during the 1973 flood.

The downstream vertical face is constructed of stone masonry and is in fair condition. Some small trees have been allowed to grow from the masonry (see Photo 7). Photos 9 and 10 show leakage from the left abutment. The cardboard box shown in Photo 9 can also be seen in Photo 8 and indicates the location of the seep in relation to the left abutment. The leakage was found to be 3 feet higher in elevation than the low-level outlet which would indicate the flow is coming through the dam or possibly around the left abutment. The flow was estimated at 7 or 8 gallons per minute.

c. Appurtenant Structures

The concrete emergency spillway is located in the center of the dam and is 13.9 feet wide (Photos 2 and 3). Over it sits an access bridge (See Photo 4). The distance between the spillway floor and the I-beams of the bridge is 3.5 feet. The spillway floor and walls are in good condition. One crack has developed in the right spillway wall and spalling has occurred along the top of the walls and several other locations. On the upstream end of the spillway are two concrete abutments which allow for the placement of 2-feet of stop logs. The stop logs are placed diagonally between the end of the spillway and the back of the gate house. The downstream vertical face of the

SECTION 2 - ENGINEERING DATA

2.1 Design Data

There is no design information available for this dam.

2.2 Construction Data

There is no significant construction data available other than a builder's plaque set into the concrete wall at the dam site, and some correspondence on file with the Vermont Department of Water Resources. The plaque indicates that the dam was constructed in 1922 by Barry, Cashman & Company, Inc., Engineers and Constructors, Boston. According to the correspondence, the spillway walls and floor slab were replaced in May of 1966. Mention was made of leakage discovered during the spillway replacement, yet no remedial measures were recorded.

2.3 Operation Data

Operational procedures have been assigned to Mr. Bruce Nelson, Plant Manager, by Mr. Rich Satterthwaite (telephone 802-422-3445). Mr. Nelson's duties involve installation and removal of stop logs, operation of the valve controlling the low-level outlet, and general supervision of the dam site. The water level of the reservoir is lowered in the fall to prevent ice damage to the gate house during the winter. In the spring the level is allowed to rise and is maintained during the summer months with the placement of stop logs for recreational purposes.

2.4 Evaluation of Data

a. Availability

The design and construction records for this dam are not available.

b. Adequacy

The structural and hydraulic adequacy of this dam could not be determined based on original design calculations and plans, but rather on visual inspection, past performance history and sound engineering judgment.

c. Validity

Not applicable.

(10) Other

Not applicable.

h. Diversion and Regulating Tunnel

Not applicable.

i. Spillway

(1) Type

Concrete spillway, acting as a broad crested weir/orifice controlled by 2 feet of stop logs.

(2) Length of Weir

13.9.

(3) Crest Elevation

1344.

(4) Gates

None.

(5) Upstream Channel

Reservoir approach channel.

(6) Downstream Channel

Natural streambed.

(7) General

Vehicle access bridge across spillway - entrance to The Farm and Wilderness Camps.

j. Regulating Outlets

The only control of the water level other than the placement or removal of the 2 feet of stop logs, is the low-level outlet. The low-level outlet has a log bar screen at the intake, measures 2-feet by 2-feet, and is made from stone. Control of the outlet is provided at the gate house with a gate and stem. Capacity for the low-level outlet at normal pool elevation is 119 CFS and at the test flood elevation is 133 CFS.

(3) Spillway Crest

101 acres.

(4) Test Flood Pool

102 acres.

(5) Top of Dam

102 acres.

g. Dam

(1) Type

Masonry-earth fill with concrete lined spillway.

(2) Length

Overall: 158 feet.

Spillway: 13.9 feet.

(3) Height

Maximum 30 feet.

(4) Top Width

48 feet.

(5) Side Slopes

Upstream: Approximately 1 on 2.

Downstream: Vertical.

(6) Zoning

None known.

(7) Impervious Core

None known.

(8) Cutoff

None known.

(9) Grout Curtain

None known.

(8) Top of Dam

1349.

(9) Test Flood Surcharge

1351.8.

d. Reservoir Data

(1) Length of Maximum Pool

5650 feet.

(2) Length of Recreation Pool

5600 feet.

(3) Length of Flood Control Pool

Not applicable.

e. Storage Data

(1) Recreation Pool

1122 acre-feet.

(2) Flood Control Pool

Not applicable.

(3) Spillway Crest Pool

918 acre-feet.

(4) Top of Dam

1428 acre-feet.

(5) Test Flood Pool

1714 acre-feet.

f. Reservoir Surface Area

(1) Recreation Pool

101 acres.

(2) Flood Control Pool

Not applicable.

- (4) Ungated Spillway Capacity at Test Flood Elevation
587 CFS at elevation 1351.8.
- (5) Gated Spillway Capacity at Normal Pool Elevation
Not applicable.
- (6) Gated Spillway Capacity at Test Flood Elevation
Not applicable.
- (7) Total Spillway Capacity at Test Flood Elevation
587 CFS at elevation 1351.8 (stop logs out).
- (8) Total Project Discharge at Test Flood Elevation
2554 CFS at elevation 1351.8.

c. Elevation Data

- (1) Streambed at Centerline of Dam
1319.4
- (2) Maximum Tailwater
Not applicable.
- (3) Upstream Portal Invert Diversion Tunnel
Not applicable.
- (4) Recreation Pool (Normal)
1346 (includes 2' of stop logs).
- (5) Full Flood Control Pool
Not applicable.
- (6) Spillway Crest
1344.
- (7) Design Surcharge (Original Design)
Unknown.

g. Purpose

The dam was originally built to act as storage and to regulate stream flow for power plants located downstream. Currently the reservoir is used solely for recreational purposes associated with The Farm and Wilderness Camps.

h. Design and Construction History

According to a bronze plaque set into the left abutment, the original dam was built in 1922. No design or construction data are available.

i. Normal Operating Procedures

There are no routine operations involved with this dam other than opening the low-level outlet in the fall and closing it and installing stop logs in the spring. The water level is lowered for the winter duration to prevent ice damage to the gate house, and is allowed to rise in the spring for summer recreational purposes.

1.3 Pertinent Data

a. Drainage Area

The total drainage area for the Woodward Reservoir includes 2.87 square miles of moderate to steep forested land. One mountain stream drains approximately 40 percent of the basin and enters the reservoir on the southwestern section. The soils within the drainage area are well drained loamy soils with mostly shallow hardpan or bedrock.

b. Discharge at the Dam Site

(1) Outlet Works

The spillway, which is 13.9 feet wide, is spanned by an access road bridge. The only other discharge is from a low-level 2-foot square stone outlet which can be controlled at the gate house.

(2) Maximum Known Flood at Dam Site

There are no flow records available for the Woodward Reservoir.

(3) Ungated Spillway Capacity at Top of Dam

438 CFS at elevation 1349.

b. Description of Dam and Appurtenances

The Woodward Reservoir Dam is 150 feet long with a maximum height of 30 feet and a top width of 48 feet. It is an earth fill masonry dam with a vertical stone downstream wall. The exposed upstream face of the dam consists of a vertical concrete face with a height of 3.7 feet and a lower part sloping 1 vertical to 2 horizontal. Dimensions of the slab are unknown.

The gate house sits above an extended concrete slab which also serves as the floor of the emergency spillway, and provides control for a 2-foot square stone low-level outlet. A log bar screen is located on the intake of the low-level outlet.

The concrete spillway is approximately 14 feet wide by 3-1/2 feet high. A bridge spans the spillway providing access to the Farm and Wilderness Camps.

Diagonally between the gate house and upstream corners of the spillway is provision for the placement of stop logs.

c. Size Classification

The dam has a maximum height of 30 feet and an impoundment of 1428 acre-feet. The United States Corps of Engineers' guidelines place dams with impoundments more than 1000 acre-feet in the intermediate classification. The Woodward Reservoir is therefore classified as intermediate.

d. Hazard Classification

A failure of the Woodward Reservoir Dam would release an initial flood wave of approximately 20 feet in height. Due to the steep mountain slopes below the dam the wave would not dissipate very quickly. Several homes are located downstream along the banks of the brook. At least three houses would receive major damage. One house sits approximately 11 feet above the stream bed, while two other homes are 14 feet above the stream bed. Therefore, the hazard classification of this dam is significant.

e. Ownership

The Woodward Reservoir and dam are currently owned by:

The Farm and Wilderness Foundation, Inc.
Plymouth Union, Vermont 05056

f. Operator

The dam is currently being maintained by the Farm and Wilderness Foundation, Inc. The contract is Mr. Rich Batterthwaite, telephone 802-422-3445. The Plant Manager is Mr. Bruce Nelson.

NATIONAL DAM INSPECTION PROGRAM
PHASE I INSPECTION REPORT
NAME OF DAM: WOODWARD RESERVOIR

SECTION 1 - PROJECT INFORMATION

1.1 General

a. Authority

Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a National Program of Dam Inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region. Dufresne-Henry Engineering Corporation has been retained by the New England Division to inspect and report on selected dams in the State of Vermont. Authorization and notice to proceed were issued to Dufresne-Henry Engineering Corporation under a letter of November 20, 1978 from Max B. Scheider, Colonel, Corps of Engineers. Contract No. DACW33-79-C-0010 has been assigned by the Corps of Engineers for this work.

b. Purpose

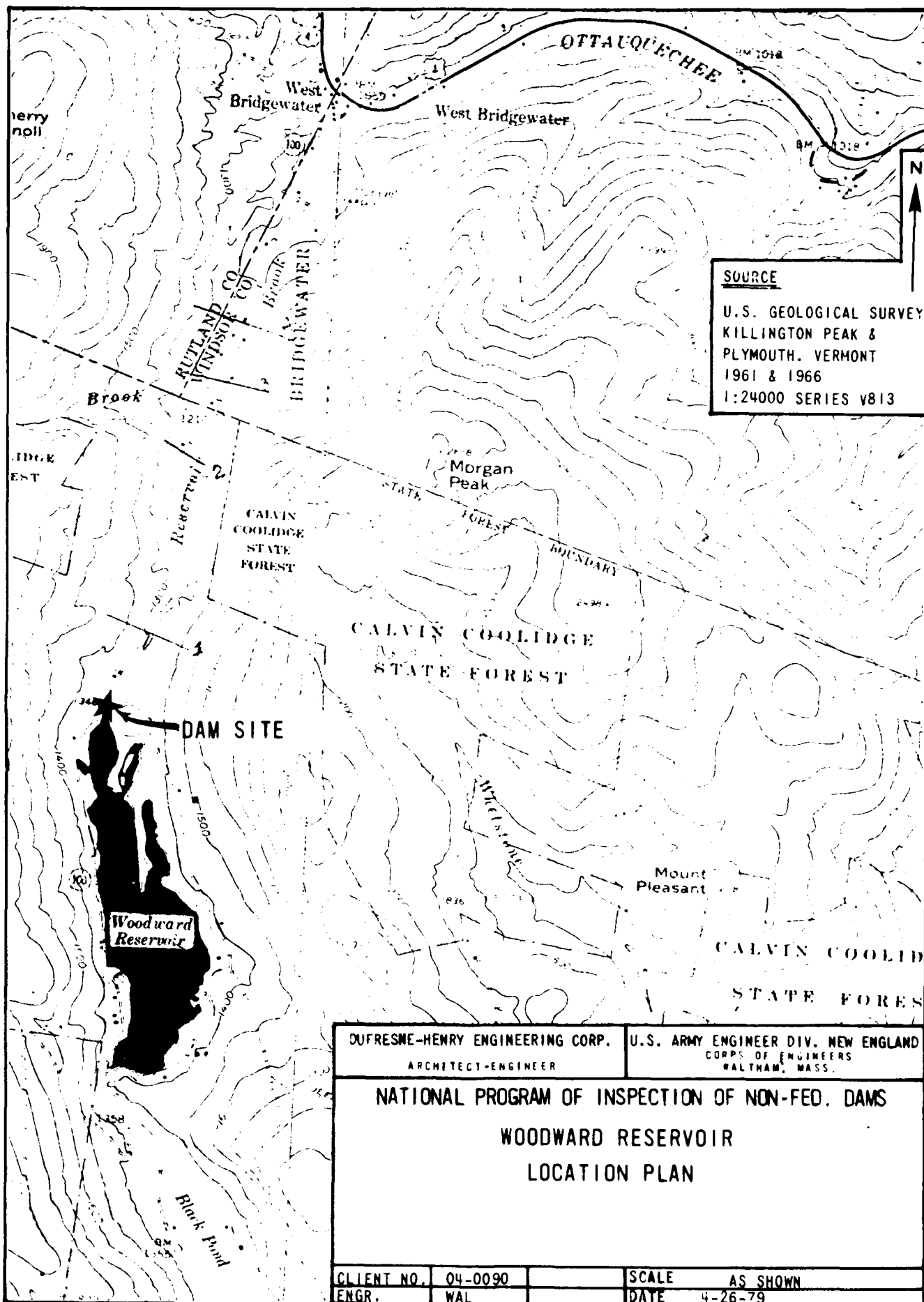
- (1) Perform technical inspection and evaluation of non-federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by nonfederal interests.
- (2) Encourage and prepare the states to initiate quickly effective dam safety programs for nonfederal dams.
- (3) To update, verify and complete the National Inventory of Dams.

1.2 Description of Project

a. Location

The Woodward Reservoir is located in the Town of Plymouth, Windsor County, Vermont, in the south central section of the State, at 43°34.5' N latitude and 72°45.7' W longitude.

The dam is located immediately adjacent to Route 100, approximately 2 miles south of West Bridgewater, Vermont. The stream below the dam, called Reservoir Brook, is a tributary of the Ottauquechee River.



SECTION 6 - STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observations

The visual inspection did not disclose any signs of immediate instability. However, the spalling, exposed reinforcement and undermining of the downstream face of the spillway significantly reduce the degree of stability of the dam.

b. Design and Construction Data

There is practically no design or construction data available and thus, the stability of the dam cannot be formally analyzed.

c. Operating Records

Available records indicate scour of spillway channel and that repairs to the channel were made. There are no other records available which are of significance with respect to stability.

d. Post-Construction Changes

There are no records of post-construction changes.

e. Seismic Stability

The dam is located in Seismic Zone 2, and in accordance with the recommended Phase I guidelines does not warrant seismic analysis.

SECTION 7 - ASSESSMENT, RECOMMENDATIONS/ REMEDIAL MEASURES

7.1 Dam Assessment

a. Condition

Based on the visual inspection, the condition of the Woodward Reservoir Dam was judged as poor. The considerable spalling and erosion of the downstream face of the spillway and the undermining of its foundation endangers the safety of the dam, particularly when water flows through the spillway.

b. Adequacy of Information

Due to very limited design and construction data, the assessment of the condition of the dam is based solely on the visual inspection and engineering judgment.

c. Urgency

The recommendations presented in Sections 7.2 and 7.3 should be carried out within one year of receipt of this report by the owner.

d. Need for Additional Investigations

There is no need for additional investigations beyond those recommended in Section 7.2

7.2 Recommendations

Plans should be prepared by a qualified engineer for the following:

- a. Repairs of the undermining at toe of the spillway and design of measures to prevent future undermining.
- b. Repair of downstream face of spillway and reconstruction of training walls.
- c. Assessment of the spillway capacity.
- d. Inspection of the outlet conduit and repairs as necessary.

The lake level should be lowered a few feet below the spillway crest without stop logs along with providing continuous monitoring during high flows and operation of the gate to minimize flows over the spillway until the recommended repairs can be implemented.

7.3 Remedial Measures

a. Operation and Maintenance Procedures

1. An annual safety technical inspection program should be instituted. It should include monitoring of the seep to the left of the spillway.
2. The routine maintenance of the dam should include repair of eroded areas, patching of minor spalling in concrete and removal of trees growing on the downstream face of the dam and from the discharge channel.
3. A formal warning plan should be prepared.

APPENDIX A

VISUAL INSPECTION CHECK LIST

PROJECT WOODWARD RESERVOIR

TIME 3:00 PM - 5:00 PM

WEATHER Clear, cool

W.S. ELEV. 1342.5 U.S. DN.S.

1. Walter A. Henry D-H

6.

2. Sherward G. Farnsworth D-H

7.

3. Gonzalo Castro GEI

8.

4. Bruce Nelson, Plant Manager,
Farm & Wilderness Foundation

9.

5. _____

10.

INSPECTED BY

REMARKS

1.

2.

3.

4.

5.

6.

8.

9.

10.

PERIODIC INSPECTION CHECK LIST

PROJECT WOODWARD RESERVOIR DATE April 23, 1979
 PROJECT FEATURE _____ NAME _____
 DISCIPLINE _____ NAME _____

AREA EVALUATED	CONDITION
<u>DAM EMBANKMENT</u> (Earth and stone masonry)	
Crest Elevation	1348.5 to 1350.
Current Pool Elevation	1342.5
Maximum Impoundment to Date	
Surface Cracks	Minor cracking, upstream face.
Pavement Condition	Gravel road.
Movement of Settlement of Crest	None apparent.
Lateral Movement	None apparent.
Vertical Alignment	None apparent.
Horizontal Alignment	Upstream face - none apparent. Downstream face - too irregular to judge.
Condition at Abutment and at Concrete Structures	Erosion at both right and left upstream abutments.
Indications of Movement of Structural Items on Slopes	Not applicable.
Trespassing on Slopes	Not applicable.
Sloughing or Erosion of Slopes or Abutments	Erosion at both right and left upstream abutments.
Rock Slope Protection - Riprap Failures	Not applicable.
Unusual Movement or Cracking at or Near Toes	Not applicable.
Unusual Embankment or Downstream Seepage	Seepage at left side embankment, 10+ feet from spillway, 3 feet above outlet.
Piping or Boils	None observed.
Foundation Drainage Features	None known.
Toe Drains	None known.
Instrumentation System	None known.
Vegetation	None

PERIODIC INSPECTION CHECK LIST

PROJECT WOODWARD RESERVOIR

DATE April 23, 1979

PROJECT FEATURE _____

NAME _____

DISCIPLINE _____

NAME _____

AREA EVALUATED	CONDITION
<u>DIKE EMBANKMENT</u>	NONE.
Crest Elevation	
Current Pool Elevation	
Maximum Impoundment to Date	
Surface Cracks	
Pavement Condition	
Movement or Settlement of Crest	
Lateral Movement	
Vertical Alignment	
Horizontal Alignment	
Condition at Abutment and at Concrete Structures	
Indications of Movement of Structural Items on Slopes	
Trespassing on Slopes	
Sloughing or Erosion of Slopes or Abutments	
Rock Slope Protection - Riprap Failures	
Unusual Movement or Cracking at or Near Toes	
Unusual Embankment or Downstream Seepage	
Piping or Boils	
Foundation Drainage Features	
Toe Drains	
Instrumentation System	
Vegetation	

PERIODIC INSPECTION CHECK LIST

PROJECT WOODWARD RESERVOIR DATE April 23, 1979
 PROJECT FEATURE _____ NAME _____
 DISCIPLINE _____ NAME _____

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - INTAKE STRUCTURE</u>	
a. Approach Channel	Below water surface, unable to pass judgment.
Slope Conditions	
Bottom Conditions	
Rock Slides or Falls	
Log Boom	
Debris	
Condition of Concrete Lining	
Drains or Weep Holes	Below water surface, unable to pass judgment
b. Intake Structure	
Condition of Concrete	
Stop Logs and Slots	

PERIODIC INSPECTION CHECK LIST

PROJECT WOODWARD RESERVOIR DATE APRIL 23, 1979
 PROJECT FEATURE _____ NAME _____
 DISCIPLINE _____ NAME _____

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - CONTROL TOWER</u>	
a. Concrete and Structural	
General Condition	Good condition.
Condition of Joints	None visible, below water level if any exist.
Spalling	Minor spalling.
Visible Reinforcing	Left corner, ice has chipped off corner, minor to total structure.
Rusting or Staining of Concrete	None observed.
Any Seepage or Efflorescence	None observed.
Joint Alignment	Not applicable.
Unusual Seepage or Leaks in Gate Chamber	None observed. Gate was shut at time of inspection.
Cracks	None observed.
Rusting or Corrosion of Steel	Not applicable.
b. Mechanical and Electrical	
Air Vents	None observed.
Float Wells	None observed.
Crane Hoist	None observed.
Elevator	None observed.
Hydraulic System	None observed.
Service Gates	Good working condition. Repaired April 1978. Hand operated.
Emergency Gates	Not applicable.
Lightning Protection System	Not applicable.
Emergency Power System	Not applicable.
Wiring and Lighting System	Not applicable.

PERIODIC INSPECTION CHECK LIST

PROJECT WOODWARD RESERVOIR DATE April 23, 1979
 PROJECT FEATURE _____ NAME _____
 DISCIPLINE _____ NAME _____

AREA EVALUATED	CONDITION
<p>OUTLET WORKS - TRANSITION AND CONDUIT</p> <p>General Condition of Concrete</p> <p>Rust or Staining on Concrete</p> <p>Spalling</p> <p>Erosion or Cavitation</p> <p>Cracking</p> <p>Alignment of Monoliths</p> <p>Alignment of Joints</p> <p>Numbering of Monoliths</p>	<p>Not Applicable.</p>

PERIODIC INSPECTION CHECK LIST

PROJECT WOODWARD RESERVOIR

DATE April 23, 1979

PROJECT FEATURE _____

NAME _____

DISCIPLINE _____

NAME _____

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - OUTLET STRUCTURE</u> <u>AND OUTLET CHANNEL</u> General Condition of Concrete Rust or Staining Spalling Erosion or Cavitation Visible Reinforcing Any Seepage or Efflorescence Condition at Joints Drain Holes Channel Loose Rock or Trees Overhanging Channel Condition of Discharge Channel	Not Applicable.

PERIODIC INSPECTION CHECK LIST

PROJECT WOODWARD RESERVOIR

DATE April 23, 1979

PROJECT FEATURE _____

NAME _____

DISCIPLINE _____

NAME _____

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - PRINCIPAL SPILLWAY</u>	
<u>WEIR, APPROACH AND DISCHARGE CHANNELS</u>	
a. Approach Channel	Under water.
General Condition	Good condition.
Loose Rock Overhanging Channel	Not applicable.
Trees Overhanging Channel	Yes.
Floor of Approach Channel	Lake bed with some sediment.
b. Weir	
General Condition of Concrete	Good.
Rust or Staining	None observed.
Spalling	Minimal.
Any Visible Reinforcing	None.
Any Seepage or Efflorescence	None.
Drain Holes	None.
c. Discharge Channel	Natural river bed.
General Condition	Good.
Loose Rock Overhanging Channel	Very steep slopes 1:1-1/2 (V-H).
Trees Overhanging Channel	Several.
Floor of Channel	Boulders.
Other Obstructions	None.
d. Spillway (Downstream Face)	Concrete Structures
General Condition of Concrete	Very poor condition for full height.
Rust or Staining	Very poor condition for full height.
Any Visible Reinforcing	Very poor condition for full height.
Drain Holes	None.
Training Walls	Very poor condition, training walls partly all gone, severe undermining.

PERIODIC INSPECTION CHECK LIST

PROJECT WOODWARD RESERVOIR

DATE April 23, 1979

PROJECT FEATURE _____

NAME _____

DISCIPLINE _____

NAME _____

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - SERVICE BRIDGE</u>	Not applicable.
a. Super Structure	
Bearings	
Anchor Bolts	
Bridge Seat	
Longitudinal Members	
Underside of Deck	
Secondary Bracing	
Deck	
Drainage System	
Railings	
Expansion Joints	
Paint	
b. Abutment & Piers	
General Condition of Concrete	
Alignment of Abutment	
Approach to Bridge	
Condition of Seat & Backwall	

PERIODIC INSPECTION CHECK LIST

PROJECT WOODWARD RESERVOIR DATE April 23, 1979
 PROJECT FEATURE _____ NAME _____
 DISCIPLINE _____ NAME _____

AREA EVALUATED	CONDITION
<u>RESERVOIR AREA</u>	
Stability of Shoreline	Some erosion.
Sedimentation	Not observable.
Changes in Watershed Runoff Potential	Minimum.
Upstream Hazards	Possibly a few homes are reached by high flows over dam crest.
Downstream Hazards	Several homes.
Alert Facilities	None known.
Hydrometeorological Gauges	None known.
Operational and Maintenance Regulations	None.

OFFICE MEMORANDUM

DATE April 6, 1966

For the Record

Donald W. Webster

SUBJECT: Woodward Reservoir Spillway Dimensions

On April 6, 1966, the writer measured the spillway section of Woodward Reservoir and found the following:

Width of spillway 14 feet 1 inch
Height of spillway walls above
spillway floor
 West side 3 feet 5½ inches
 East side 3 feet 4½ inches

This gives a capacity flow based on a coefficient $C = 3.3$
of ~~247~~ cubic feet per second.

287

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- (2) Installation of a suitable apron below the overflow channel to check scour at the base, and
- (3) possibly, some relief of the congestion at the entrance to the overflow channel.

BY Stephen H. Haybrook
STEPHEN H. HAYBROOK
HYDRAULIC ENGINEER

Public Service Commission
December 9, 1952

horizontal slope.

Directly underneath is a low level, regulated outlet. It is 3 ft. dia. conduit equipped with gates and trash rack at the upstream end. The gate house sits at the entrance to the overflow channel.

Comments on inspection

The dam was more recently inspected on Nov. 16, 1952 at a time when the reservoir was well drawn down. Observations were as follows:

- (1) On the downstream side, the stone masonry wall shows a localized weakened condition in the vicinity of the overflow. A concrete lining below the overflow channel to provide a water face down the vertical wall is deeply scoured from the action of water. Also, there is some foundation scour at the base because of the uncontrolled vertical 25 ft. drop of any water passing through the overflow.
- (2) The concrete lining on the upstream face shows spalling and cracking mainly in the upper portions.
- (3) The overflow channel also shows a surface condition.
- (4) There is congestion at the entrance to the overflow channel due to the location of the gate house directly in line and in close proximity.
- (5) The structure has a massive section which enhances its stability in general.

Conclusions:

In the writer's summary report on dams, this structure was classified in Group II as being capable of some damage in the event of failure. As such, it should be maintained in a reasonable condition. Particular attention may be directed to:

- (1) Maintenance repairs,

REPORT ON
WOODWARD RESERVOIR DAM

Dam: Hydro-electric

*Bridgewater Elec.
Co.*

or Woodstock Elec.

Woodward Reservoir dam is owned and operated by a group of water power operators, among which are two electric utilities. Because of this connection the dam is reported to this Commission.

Pertinent data

1. Location of Dam - Tributary of Ottauquechee River, town of Plymouth.
2. Owners of dam - Bridgewater Woolen Co., Woodstock Electric Company, Harris Emery Co., and A. G. Dewey Co. - combined to form the Woodward Reservoir Corp.
3. Purpose of dam - Storage for stream flow regulation for power plants downstream.
4. Size of reservoir - Surface area is given as 100 acres, volume is estimated at 40,000,000 cu. ft.
5. Drainage area - About 2 sq. mi.

Description of the dam

This dam is essentially an embankment retained by an unpaved masonry wall on the downstream side. It measures about 150 ft. long and 30 ft. high at the maximum section. It has a top width of about 50 ft. While the downstream face is vertical, the upstream face slopes at about 1 on 1. The latter is protected by a concrete slab which also serves as a flow retarding element. The dam is on a hard pan foundation.

A rectangular, concrete-lined overflow channel is provided near the west end. It is 4 ft. deep and 14.5 ft. wide and has a practically

Dam: Hydro-electric

June 9, 1953

Mr. Carl Bennett, Supt.
Woodstock Electric Company
Woodstock, Vermont

Dear Mr. Bennett:

I understand that your company has an interest in the Woodward Reservoir dam located in the town of Plymouth. For this reason I am sending you a copy of my report on the structure as submitted to the Commission after an inspection last fall.

I have again inspected this dam in May and found, for additional comments, the overflow cluttered with debris, a minor seepage condition, and insufficient freeboard.

Your attention is invited to my appraisal of the fitness of this dam.

Very truly yours,

STEPHEN H. HAYBROOK
HYDRAULIC ENGINEER

SHH/ef

Enc.

Hand: Hydro-electric

June 9, 1953

Mr. R. M. Sharpe, Vice Pres.
Bridgewater Electric Company
Bridgewater, Vermont

Dear Mr. Sharpe:

I understand that your company has an interest in the Woodward Reservoir dam located in the town of Plymouth. For this reason I am sending you a copy of my report on the structure as submitted to the Commission after an inspection last fall.

I have again inspected this dam in May and found, for additional comments, the overflow cluttered with debris, a minor seepage condition, and insufficient freeboard.

Your attention is invited to my appraisal of the fitness of this dam.

Yours very truly,

STEPHEN H. HAYBROOK
HYDRAULIC ENGINEER

SHH/ef

Enc.

OFFICE MEMORANDUM

TO: For the Record
FROM: Andre J. Rouleau
SUBJECT: Woodward Reservoir (Plymouth Pond), Plymouth, Vermont
DATE: December 30, 1970

Received a telephone call from Mr. Earl Cram on December 28, 1970, who has a camp on the pond. He was concerned about the procedure for registering concern about the management of water levels of the pond. I had suggested to a colleague of his that he should write a letter outlining the problem.

In general, the lake is drawn down in a 2 to 3 week period, to about 12 to 15 feet below normal summer level. There is more than 20 acres left when the lake is drained to the bottom of the dam.

In 1969, drawdown commenced in mid-August in order to repair docks at the Webb's. Actual repair started in early November.

In 1970, drawdown commenced in mid-August to repair the dam. Actual repair started in early November.

The point that Mr. Cram makes is that these objectives could still be attained without an early drawdown which adversely affects the other landowners on the pond and also the general public who views the lake and use the Fish and Game Department access.

He also wished to alert us about a building foundation on the lakeshore in the vicinity of an island which is about 2 feet above the water level (southerly of the fishing access). The reported price paid is \$25,000. for 1½ acres, which leads him to expect a major use of that land with no apparent solution to pollution.

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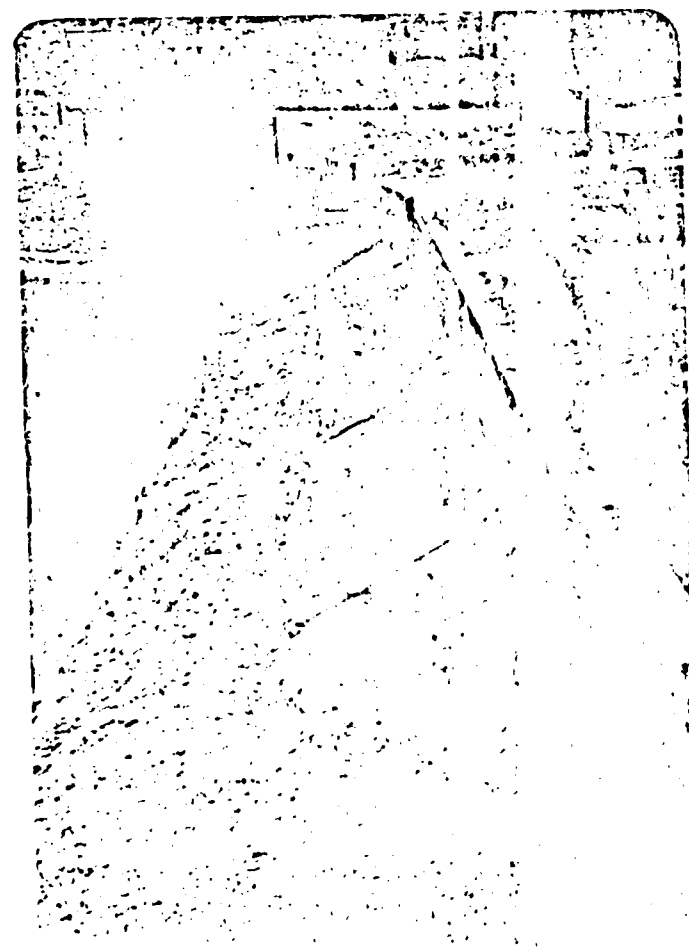
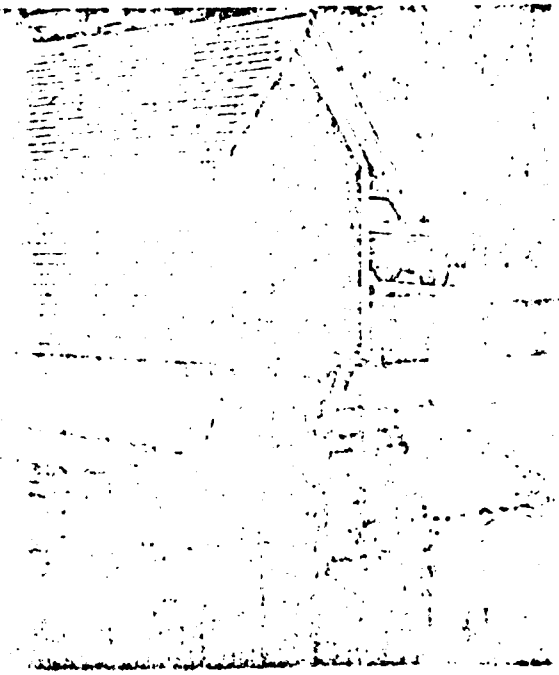
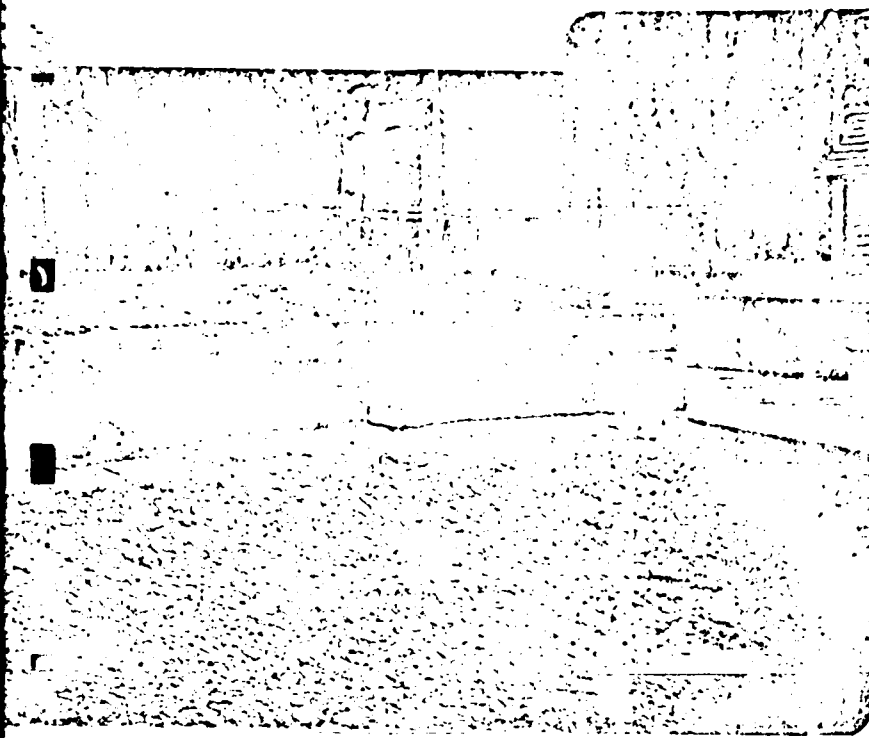
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INFORMATION SHEET

Additional Remarks:

PLYMOUTH

11-8-78

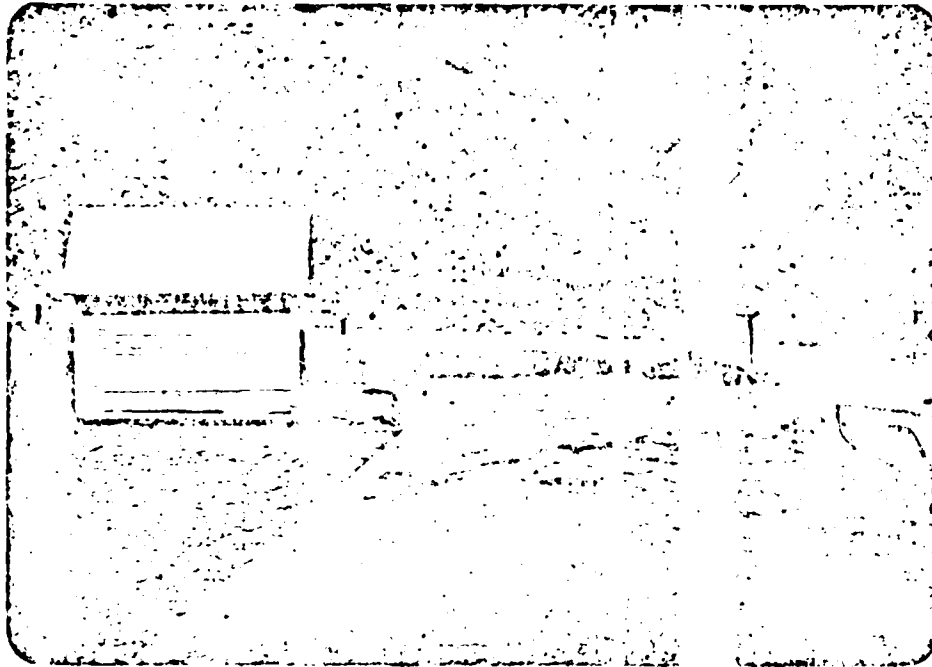


Photos
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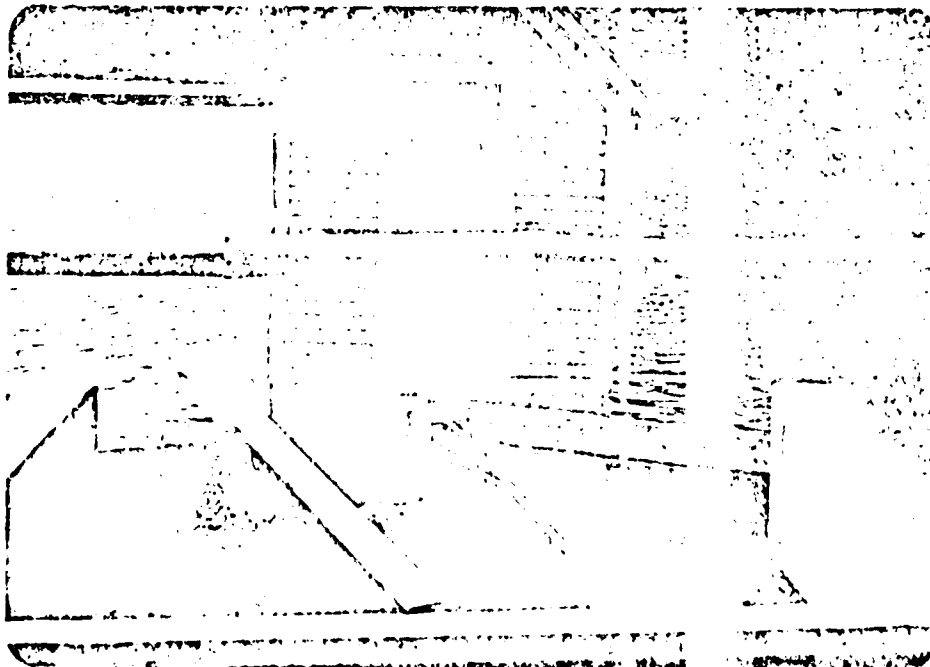
WOODWARD RESERVOIR DAM

PLYMOUTH

JUNE 14, 1974



LOOKING W.
RTE. 100
IN BACKG-



LOOKING SOUT.
FROM BRIDGE
OVER SPILLWA

PHOTO-3
6-14-74

Remarks: The above questions are framed for a pond TO BE CONSTRUCTED. This is a repair job which doesn't need doing now, but is more convenient now because the Town is putting in a new bridge over the spillway with I-beams! We propose to re-surface the floor of the spillway 4-6 deep -- perhaps 2" would be sufficient; we'll be glad of your counsel -- to set up new side walls just inside the present cracking walls, probably 8" thick (let us if you think less would do). Since the men and equipment are about thru working at the Camps, we would like to catch them Signed: Donald Webster
(owner)

now, to save expense. Please let us here from you soon: Name of Engineer, if any

-- And Donald Webster,

my thanks for calling yesterday rather than writing. KBW.

Note No. 1: Enclose with this application the Plans and Specifications.

Note No. 2: Enclose copy of letter of notice to selectmen of the town in which such dam is to be located.

Form WR-33

APPLICATION FOR CONSTRUCTION PERMIT FOR DAM

Owner FARM AND WILDERNESS CAMPS

Date APRIL 1st, 1966

P. O. Address Plymouth Union

Tel. No. 457-2141 (Wdstk)

Location of Structure:

Town Plymouth

Shown on USGS Quadrangle

Name of Stream Lake: Woodward Reservoir

at inches south of Lat.

north

and inches east of Long.

west

Directions for reaching site from nearest village or route intersection:

(see sketch on reverse side) Turn south on Rte 100 from Route 4 at West Bridgewater.

This is an application for: (New Construction) (Alteration) (Repair) (Removal)

(check one or more of above)

This pond is to be used for: swimming, canoeing, fishing, etc.

Dimensions of Pond: width $\frac{1}{2}$ mile length $1\frac{1}{2}$ miles area Somebody said 100 acres.

Maximum depth of water immediately above dam: c. 10 feet

Volume of water in cubic feet over 500,000

Total length of dam: 148 ft

Crest width of spillway: 14'

Height of dam: 20 ft

Width of top: 48 ft

Width of base: ~~approx 70 ft~~

Type of spillway construction: cement

Type of dam construction: cement (with earth fill?)

Spillway section will be set on: (Bedrock) (Gravel) (Clay) (Till) cement

(check one of above)

APPENDIX B
PROJECT RECORDS AND PLANS

OFFICE MEMORANDUM

DATE May 10, 1966

TO: For the Record

FROM: Donald W. Webster

SUBJECT: Woodward Reservoir Dam

On May 10, 1966, the writer went to the Woodward Reservoir to inspect the status of the outlet structure in accordance with instructions from the Commissioner's office. The contractor was on the scene and in conjunction with the writer, looked over the conditions at the outlet. The concrete wingwalls and sidewalls of the spillway had been removed preparatory to replacement. The floor slab of the spillway was still in place. A readily apparent leakage under the spillway was visible from the area where the sidewalls were formally located. The holes under the slab apparently extend throughout most of the dam. However, the full extent is not visible so long as the slab remains in place. The contractor wanted advise as to repair and was instructed that the Department of Water Resources was not going to supply such technical assistance but that Mr. Webb, the owner, had promised in October of 1965, that he would contact Peter Gratiot of Woodstock for engineering assistance. The contractor was told by the writer that the State of Vermont would suggest to Mr. Webb that the services of a professional engineer, Peter Gratiot et al, be obtained and that the spillway floor be removed in order that a full visual inspection could be made by the engineer in preparing a method of repair. He promised to convey this to Mr. Webb.

The other two items that Mr. Webb was concerned about; the septic tank situation and the filling of the lake, were checked into by the writer. It does appear that two new camps have been constructed on Woodward Reservoir at which septic tanks are being installed with no leaching field and in fact, direct discharge from the tank to the reservoir. This matter should be looked into by our Water Pollution Control Inspector. The second problem of filling into the reservoir concerns an area perhaps 100 feet square about one-quarter mile south of the outlet structure. The contractor was told that there is no State statute inforceable by this Department which can prevent such occurrences. Indeed, there would be some question as to this Department's responsibility even if the "Lands under Public Waters" Bill had been enacted by the last session of the Legislature as an determination would have to be made as to whether this is initially a public water of the State of Vermont or whether if a probably artificial reservoir falls in the realm of private property.

ROUTING		
GENERAL		
TO	NOTED	DATE
DWW	DWW	5-11
J.C.	J.C.	5-11
RWT	J.	5-17



FARM AND WILDERNESS CAMPS

Timberlake • Indian Brook • Tamarack Farm • Saltash Mountain • Flying Cloud

PLYMOUTH UNION, VERMONT 05057

WINTER ADDRESS: Woodstock, Vermont 05091

October 22, 1965

Mr. Rheinhold Thieme
Commissioner, Department of Water Resources
Montpelier, Vermont

Dear Mr. Thieme:

I am still awaiting a reply to my letter of some time ago to you about inspection by a competent engineer of the dam on the Woodward Reservoir.

Personally, I am not in the least concerned about the condition of the dam, for I think it is all right, and that the small loss of water has been going on for years, probably, and presents no danger of anything more. However, if we have got to let down the water, I want to do it before cold weather, since we have to close the dam by the time the water starts to freeze in order to get a good head for another year.

Will you please let us know, therefore, whether to forget about this, or to expect a visit from your engineer. If the latter, I should be glad to know when, so I can get a chance to go out there with him and open the gatehouse, and also discuss the whole thing with him. After Friday of this week, I shall be in Woodstock.

Sincerely,

Kenneth B. Webb

Kenneth B. Webb

Kow/fm

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FARM AND WILDERNESS CAMPS

Timberlake • Indian Brook • Tamarack Farm • Saltash Mountain • Flying Cloud

PLYMOUTH UNION, VERMONT 05057

WINTER ADDRESS: Woodstock, Vermont 05091

October 11, 1965

Mr. Rhoimhold Thieme
Department of Water Resources
Montpelier, Vermont

Dear Mr. Thieme:

You may remember our little talk at the spring meeting of the Vermont Camping Association.

We have a problem here about which Rex Jillson may possibly have written you. We have been losing a little water through our dam on Plymouth Pond (Woodward Reservoir). It is not a bad leak, and it has probably been going on for years, but we should like to have it inspected by some competent engineer. Since the lake has a capacity of over 500,000 gallons, Rex said that you people should be brought in on this.

I should be happy to know of when such an engineer might come, so that I could be there and talk with him. Of course we are very anxious to save any large bill at the present time, since we have not budgeted it, but I suppose we will have to do what is immediately essential for the safety of the dam.

Sincerely,

Kenneth B. Webb

Kenneth B. Webb

kbw/fm

ROUTING		
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TO	NOTED	DATE
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<i>JEC</i>	<i>DWW</i>	<i>10-22</i>
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OFFICE MEMORANDUM

DATE October 26, 1965

For the Record

Donald W. Webster

SUBJECT: Woodward Reservoir

*Telephone Call
Oct. 25, 65*

The writer contacted Mr. Kenneth B. Webb of Farm and Wilderness Camps, Woodstock, Vermont, in regard to the leak at the dam on Woodward Reservoir. It appears that although there has been surface deterioration of the masonry face of the dam over the years, the problem involved at the present time, however, is that of a leak around the gate structure. After discussion with Mr. Webb, he was advised that this probably would fall in the nature of repair rather than of reconstruction of the dam. However, he was further advised that should an investigation show that the dam or a portion would have to be reconstructed then it would not be either ethical or legally possible for the Department or representatives thereof to take an active part in the design of any improvements.

Mr. Webb stated he was cognizant of this and the reasons for it, and agreed that he would contact Mr. Peter Gratiot for advice, and if the matter was simple repair or maintenance then there would be no further need for action by this Department. If, however, it should necessitate reconstruction or other involved work, then this Department will be advised and the necessary legal requirements will be met.

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RWT	<i>E</i>	



FARM AND WILDERNESS CAMPS

Timberlake • Indian Brook • Tamarack Farm • Saltash Mountain • Flying Cloud

PLYMOUTH UNION, VERMONT 05057

WINTER ADDRESS: Woodstock, Vermont 05091

April 1st, 1966

Messrs. Rola Davis, Chm.
Harvey Gray
Donald K. Martin

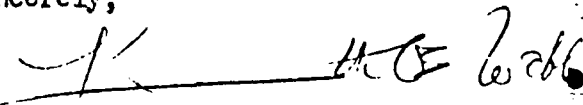
Dear Friends:

This is just to inform you in compliance with the law that we are going to make the minor repairs on the spillway at Woodward before you put in the new bridge. We are applying to the Water Resources Board for permission to make these repairs, since they are required to assure the safety of any dam impounding more than 500,000 callons of water.

Incidentally, we find that the lake is regarded as "private", since it was formed originally by building the dam. This is news to us, and interesting, since if some of those throttle-happy water-skiers who prefer to infest small lakes rather than going to Bomoseen or Champlain become too dangerous to our canoeists from the three camps on the Reservoir, we may be able to do something about it.

We certainly are glad to have the I-beams going in (and we hope a slightly wider bridge) for it was sometimes hard to persuade a new driver of one of the big busses at the start of camp that he should go over that old wooden bridge. Our only talking-point was that the bridge hadn't gone thru yet!

Sincerely,



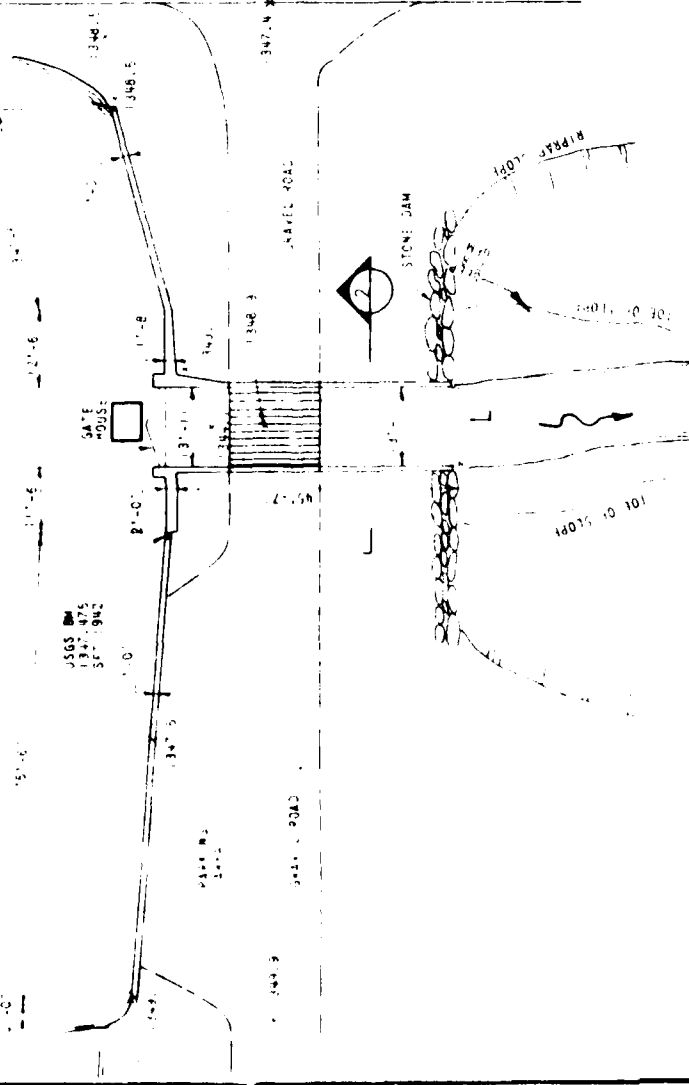
P.S. Merriam is just waiting for the above permission from the WFB to get started on this job. KM

WOODWARD RESERVOIR
WATER LEVEL ON 6-14-74
EL. 1345.6 MSL

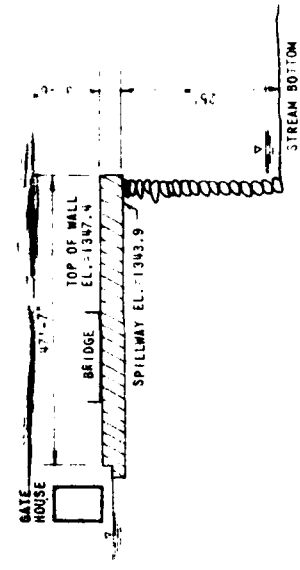
STOP LOG STRUCTURE
2'-0" IN PLACE
SEP. 1962

USGS
JUGGS BR.
JUGGS BR.
JUGGS BR.
JUGGS BR.
JUGGS BR.

GATE HOUSE



ROUTE 100



SECTION 1
N.T.S.



SECTION 2
N.T.S.

SOURCE

TAKEN FROM SURVEY 6-14-74
BY VT. DEPT. OF WATER RESOURCES
A.F.B. - D.J.M.

VERMONT
PLANNING
NATIONAL PROGRAM OF INSPECTION OF NON-FEEL DAMS
WOODWARD RESERVOIR DAM
PLAN & SECTIONS
SCALE N.T.S.
CLIENT: BUREAU OF VERMONT
PROJECT: 04-0090
DATE: 11/1/74
BY: A.F.B. - D.J.M.

PLAN
N.T.S.

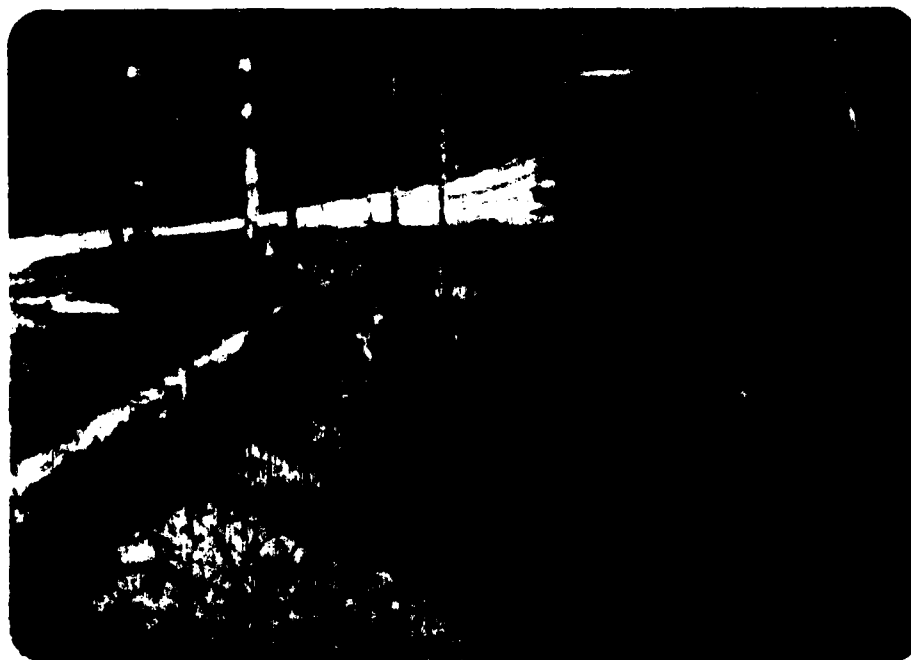
APPENDIX C

PHOTOGRAPHS

1. View from right abutment showing gate house.
2. View showing left abutment, gate house, spillway and access bridge.
3. View showing gate house, spillway and bridge.
4. Close-up of spillway and access bridge.
5. View of right abutment.
6. Downstream view of low-level outlet.
7. View of downstream channel and downstream masonry face.
8. Close-up of downstream face showing exposed reinforcing and remains of training walls.
9. View showing seep downstream of dam.
10. Close-up of seep.



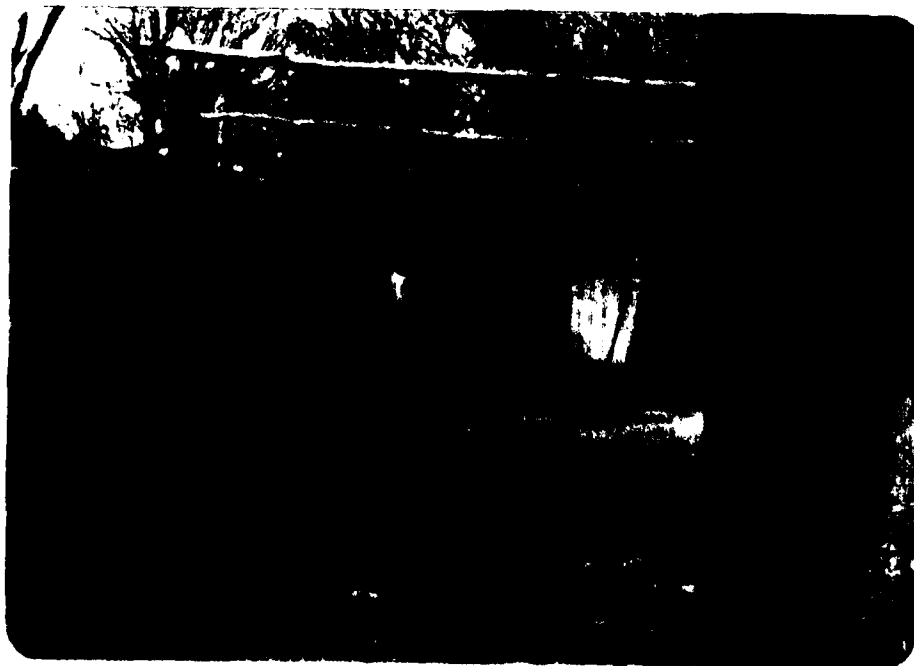
#1. VIEW FROM RIGHT ABUTMENT SHOWING GATE HOUSE



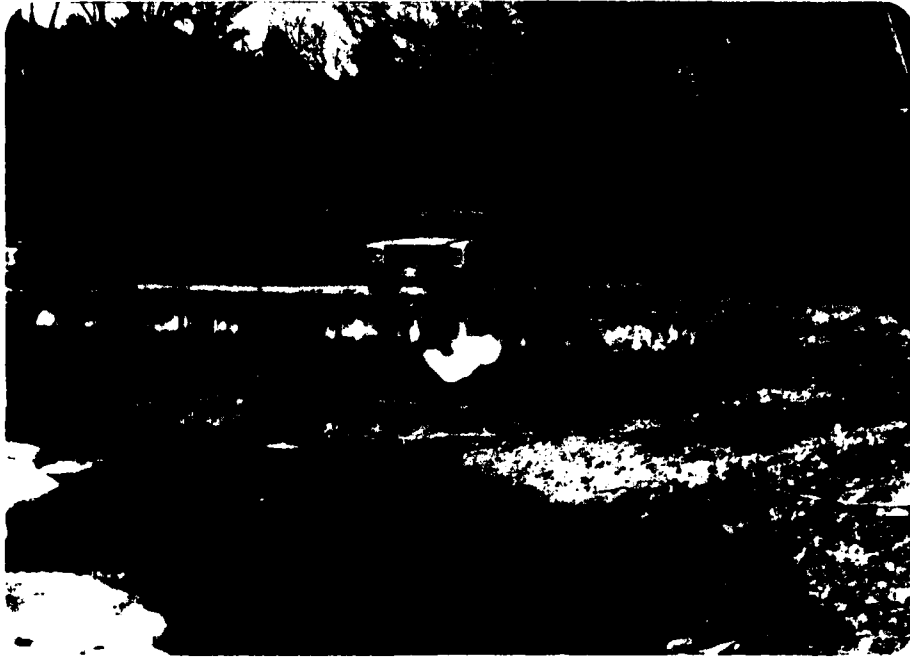
#2. VIEW SHOWING LEFT ABUTMENT, GATE HOUSE, SPILLWAY AND ACCESS BRIDGE



#3. VIEW SHOWING GATE HOUSE, SPILLWAY AND BRIDGE



#4. CLOSE-UP OF SPILLWAY AND ACCESS BRIDGE



#5. VIEW OF RIGHT ABUTMENT



#6. DOWNSTREAM VIEW OF LOW-LEVEL OUTLET



#7. VIEW OF DOWNSTREAM CHANNEL AND DOWNSTREAM
MASONRY FACE



#8. CLOSE-UP OF DOWNSTREAM
FACE SHOWING EXPOSED
REINFORCING AND REMAINS
OF TRAINING WALLS

APPENDIX D

HYDROLOGIC AND HYDRAULIC COMPUTATIONS



#9. VIEW SHOWING SEEP DOWNSTREAM OF DAM. NOTE
CARDBOARD BOX LOCATION IN THIS PHOTO AND IN
PHOTO #8.



#10. CLOSE-UP OF SEEP

DUFRESNE-HENRY ENGINEERING CORPORATION

W.A. LEONARD
DATE 3-29-78

SUBJECT WOODWARD RESERVOIR
TEST FLOOD

SHEET NO. 2 OF 33
JOB NO. 04-0090

TEST FLOOD

FOR SMALL DAM WITH SIGNIFICANT HAZARD -
TEST FLOOD 100YR \rightarrow 1/2 P.M.F.

FOR 100YR FLOOD - FROM SOILS CONSERVATION SERVICE
100YR RAINFALL = 5.6" (47-3)
DOMINANT SOIL TYPE "C"
CURVE No 73
SLOPE MODERATE

FROM ES -1027

100YR PEAK DISCHARGE = 1150 CFS.

FROM TABLE 2-2; $(.75)(1150) = \underline{\underline{863 \text{ CFS}}}$

FOR 1/2 P.M.F - FROM CORPS OF ENGINEERS MAXIMUM PROBABLE
DISCHARGES IN PHASE I DAM SAFETY INVESTIGATION
FROM GRAPH USING 3.87 SQ MI
 $1/2 \text{ PMF} = .5(2450)(2.87) = 3516 \text{ CFS}$
 $.75(3516) = 2637 \text{ C.F.S.}$

USE 1/2 P.M.F FOR TEST FLOOD, DUE TO THE NUMBER
OF HOMES DOWNSTREAM

FROM HEC-1 COMPUTER PROGRAM

TEST FLOOD (1/2 P.M.F) = 4732 CFS

ROUTED TEST FLOOD OUTFLOW = 2554 CFS

USE 2554 FOR TEST FLOOD

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RUNOFF MULTIPLIED BY 0.50									
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2.	2.	2.	2.	2.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
45.	65.	87.	109.	128.	146.	158.	168.	176.	180.
185.	189.	192.	195.	197.	198.	199.	200.	201.	202.
202.	202.	203.	203.	203.	203.	203.	203.	203.	203.
203.	203.	203.	203.	203.	203.	203.	203.	203.	203.
1124.	1254.	1376.	1481.	1577.	1669.	1754.	1832.	1904.	2024.
2128.	2291.	2529.	2835.	3217.	3691.	4085.	4445.	4671.	4732.
4636.	4620.	6124.	6740.	7476.	8145.	8754.	9277.	9671.	9877.
2186.	4952.	1722.	1442.	1242.	1015.	814.	651.	519.	481.
444.	427.	410.	393.	378.	363.	348.	336.	321.	308.
296.	264.	231.	202.	172.	142.	112.	82.	52.	206.
192.	190.	182.	175.						

CFS	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
14085	4732.	2625.	750.	740.	113719.
AC-PT		8.51	10.24	10.24	10.24
		1302.	1507.	1507.	1507.

1 13 00	0.31	0.49	4313.
1 13 10	0.38	0.36	1625.
1 13 20	0.38	0.36	1594.
1 13 30	0.38	0.36	2248.
1 13 40	0.38	0.36	2516.
1 13 50	0.38	0.36	2752.
1 13 60	0.38	0.36	2962.
1 14 10	0.47	0.45	3153.
1 14 20	0.47	0.45	3338.
1 14 30	0.47	0.45	3517.
1 14 40	0.47	0.45	3693.
1 14 50	0.47	0.45	3868.
1 14 60	0.47	0.45	4042.
1 15 10	1.20	1.10	4255.
1 15 20	1.20	1.10	4502.
1 15 30	1.20	1.10	5051.
1 15 40	1.20	1.10	5670.
1 15 50	1.20	1.10	6336.
1 15 60	1.20	1.10	7305.
1 16 10	0.44	0.42	6171.
1 16 20	0.44	0.42	6850.
1 16 30	0.44	0.42	7383.
1 16 40	0.44	0.42	7666.
1 16 50	0.44	0.42	7771.
1 16 60	0.44	0.42	8850.
1 17 10	0.35	0.33	8257.
1 17 20	0.35	0.33	7597.
1 17 30	0.35	0.33	8952.
1 17 40	0.35	0.33	8390.
1 17 50	0.35	0.33	5909.
1 17 60	0.35	0.33	5493.
1 18 10	0.03	0.01	5117.
1 18 20	0.03	0.01	6731.
1 18 30	0.03	0.01	6332.
1 18 40	0.03	0.01	3965.
1 18 50	0.03	0.01	3665.
1 18 60	0.03	0.01	2966.
1 19 10	0.03	0.01	4985.
1 19 20	0.03	0.01	4026.
1 19 30	0.03	0.01	1626.
1 19 40	0.03	0.01	1301.
1 19 50	0.03	0.01	1031.
1 19 60	0.03	0.01	925.
1 20 10	0.03	0.01	888.
1 20 20	0.03	0.01	859.
1 20 30	0.03	0.01	819.
1 20 40	0.03	0.01	787.
1 20 50	0.03	0.01	755.
1 20 60	0.03	0.01	725.
1 21 10	0.03	0.01	657.
1 21 20	0.03	0.01	609.
1 21 30	0.03	0.01	662.
1 21 40	0.03	0.01	617.
1 21 50	0.03	0.01	562.
1 21 60	0.03	0.01	569.
1 22 10	0.03	0.01	566.
1 22 20	0.03	0.01	526.
1 22 30	0.03	0.01	501.
1 22 40	0.03	0.01	486.
1 22 50	0.03	0.01	466.
1 22 60	0.03	0.01	446.
1 23 10	0.03	0.01	426.
1 23 20	0.03	0.01	411.
1 23 30	0.03	0.01	391.
1 23 40	0.03	0.01	379.
1 23 50	0.03	0.01	366.

	8 28 00	0.03	0.01	3502	
	SUN	22.66	19.98	227477.	
	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	9464.	5249.	1580.	1580.	227479.
INCHES		17.01	20.48	20.48	
AC-FT		2804.	3135.	3135.	3135.

MPC-1 VERSION DATED JAN 1973
UPDATED AUG 74
CHANGE NO. 01

WECARD RESERVOIR PLYMOUTH VERMONT
PARK AND WILDERNESS FOUNDATION INC
RESERVOIR ROUTING PROGRAM

JOB SPECIFICATION
NQ 144 RMR 0 NMN 10 IDAY 1 IMA 0 IAIN METRC 0 IPLT 2 IPAT 0 ASTAN 0
JOPEB NWT
3 0

SUB-AREA RUNOFF COMPUTATION

SUB AREA RUNOFF
1STA2 1 ICGPP 0 IECCH 0 ITAPE 0 JPLT 0 JPAT 0 INAME 1

HYDROG 1 IUNG 1 YAREA 2.87 SNAP 0.0 MICROGRAPH DATA
TRSDA TRSPC RATIO ISNCH ISAPE LOCAL
0.0 0.0 1.00 0.00 0.00 0.00 0.00 0.00

PRECIP DATA
R12 R24 R48 R72 R96
0.0 17.00 111.00 123.00 133.00 0.0 0.0 0.0

LOSS DATA
STRAK OLTKR RTIOL ERAIN STAKS RTIOK STRYL CASTL ALSAK RTIMP
0.0 0.0 1.00 0.0 0.0 1.00 0.30 0.12 0.0 0.0

UNIT HYDROGRAPH DATA
TPB 1.18 CP0.75 NTAB 0

RECESSION DATA

STRYCR 5.70 CRCSNB -0.10 RTIOB 1.50

APPROXIMATE CLARK COEFFICIENTS FROM GIVEN SNOWDR CP AND TP ARE TCR 0.56 AND RA 4.28 INTERVALS

UNIT HYDROGRAPH 28 END-OF-PERIOD ORDINATES, LAGS 1.17 HOURS, CP 0.75 VOL 1.00
66. 237. 403. 706. 930. 1110. 1191. 1182. 1083. 866.
886. 568. 429. 340. 264. 212. 164. 133. 105. 83.
88. 92. 41. 33. 26. 20. 16. 13. 10. 8.

END-OF-PERIOD FLOW

TIME	RAIN	EXCS	COMP Q
1 0 15	0.02	0.00	5.
1 0 20	0.02	0.00	5.
1 0 30	0.02	0.00	5.
1 0 40	0.02	0.00	5.
1 0 50	0.02	0.00	5.
1 0 55	0.02	0.00	5.
1 1 00	0.02	0.00	5.
1 1 05	0.02	0.00	5.
1 1 10	0.02	0.00	5.
1 1 15	0.02	0.00	5.
1 1 20	0.02	0.00	5.
1 1 25	0.02	0.00	5.
1 1 30	0.02	0.00	5.
1 1 35	0.02	0.00	5.
1 1 40	0.02	0.00	5.
1 1 45	0.02	0.00	5.
1 1 50	0.02	0.00	5.

2	1 00	0.02	0.00	0.
1	2 10	0.02	0.00	3.
1	2 20	0.02	0.00	3.
1	2 30	0.02	0.00	3.
1	2 40	0.02	0.00	3.
1	2 50	0.02	0.00	3.
1	2 60	0.02	0.00	3.
1	3 10	0.02	0.00	3.
1	3 20	0.02	0.00	3.
1	3 30	0.02	0.00	2.
1	3 40	0.02	0.00	2.
1	3 50	0.02	0.00	2.
1	3 60	0.02	0.00	2.
1	4 10	0.02	0.00	2.
1	4 20	0.02	0.00	2.
1	4 30	0.02	0.00	2.
1	4 40	0.02	0.00	2.
1	4 50	0.02	0.00	2.
1	4 60	0.02	0.00	2.
1	5 10	0.02	0.00	2.
1	5 20	0.02	0.00	2.
1	5 30	0.02	0.00	1.
1	5 40	0.02	0.00	1.
1	5 50	0.02	0.00	1.
1	5 60	0.02	0.00	1.
1	6 10	0.06	0.00	4.
1	6 20	0.06	0.00	12.
1	6 30	0.06	0.00	29.
1	6 40	0.06	0.00	59.
1	6 50	0.06	0.00	89.
1	6 60	0.06	0.00	110.
1	7 10	0.06	0.00	119.
1	7 20	0.06	0.00	217.
1	7 30	0.06	0.00	250.
1	7 40	0.06	0.00	288.
1	7 50	0.06	0.00	313.
1	7 60	0.06	0.00	333.
1	8 10	0.06	0.00	365.
1	8 20	0.06	0.00	361.
1	8 30	0.06	0.00	371.
1	8 40	0.06	0.00	374.
1	8 50	0.06	0.00	385.
1	8 60	0.06	0.00	389.
1	9 10	0.06	0.00	393.
1	9 20	0.06	0.00	398.
1	9 30	0.06	0.00	399.
1	9 40	0.06	0.00	401.
1	9 50	0.06	0.00	402.
1	9 60	0.06	0.00	403.
1	10 10	0.06	0.00	404.
1	10 20	0.06	0.00	405.
1	10 30	0.06	0.00	405.
1	10 40	0.06	0.00	406.
1	10 50	0.06	0.00	406.
1	10 60	0.06	0.00	406.
1	11 10	0.06	0.00	406.
1	11 20	0.06	0.00	406.
1	11 30	0.06	0.00	406.
1	11 40	0.06	0.00	406.
1	11 50	0.06	0.00	406.
1	11 60	0.06	0.00	406.
1	12 10	0.31	0.29	423.
1	12 20	0.31	0.29	484.
1	12 30	0.31	0.29	603.
1	12 40	0.31	0.29	785.
1	12 50	0.31	0.29	1027.

DUFRESNE-HENRY ENGINEERING CORPORATION

BY W.A. LEONARD
DATE 3-29-79

SUBJECT WOODWARD RESERVOIR
HEC-1 COMPUTER INPUT DATA

SHEET NO. 6 OF 33
JOB NO. 04-0090

SOIL HYDROLOGIC GROUP "C"
RUNOFF CURVE NO. 73

USING A WET CONDITION:

INITIAL RAINFALL LOSSES .30 INCHES
INFILTRATION RATE .12 INCHES/HOUR

AVERAGE SLOPE

ELEV @ 10% 1580
ELEV @ 85% 3000
TOTAL DISTANCE 2.84 MILES

$$\frac{3000 - 1580}{(.75)(2.84)} = 666.5 \text{ FT/MILE}$$

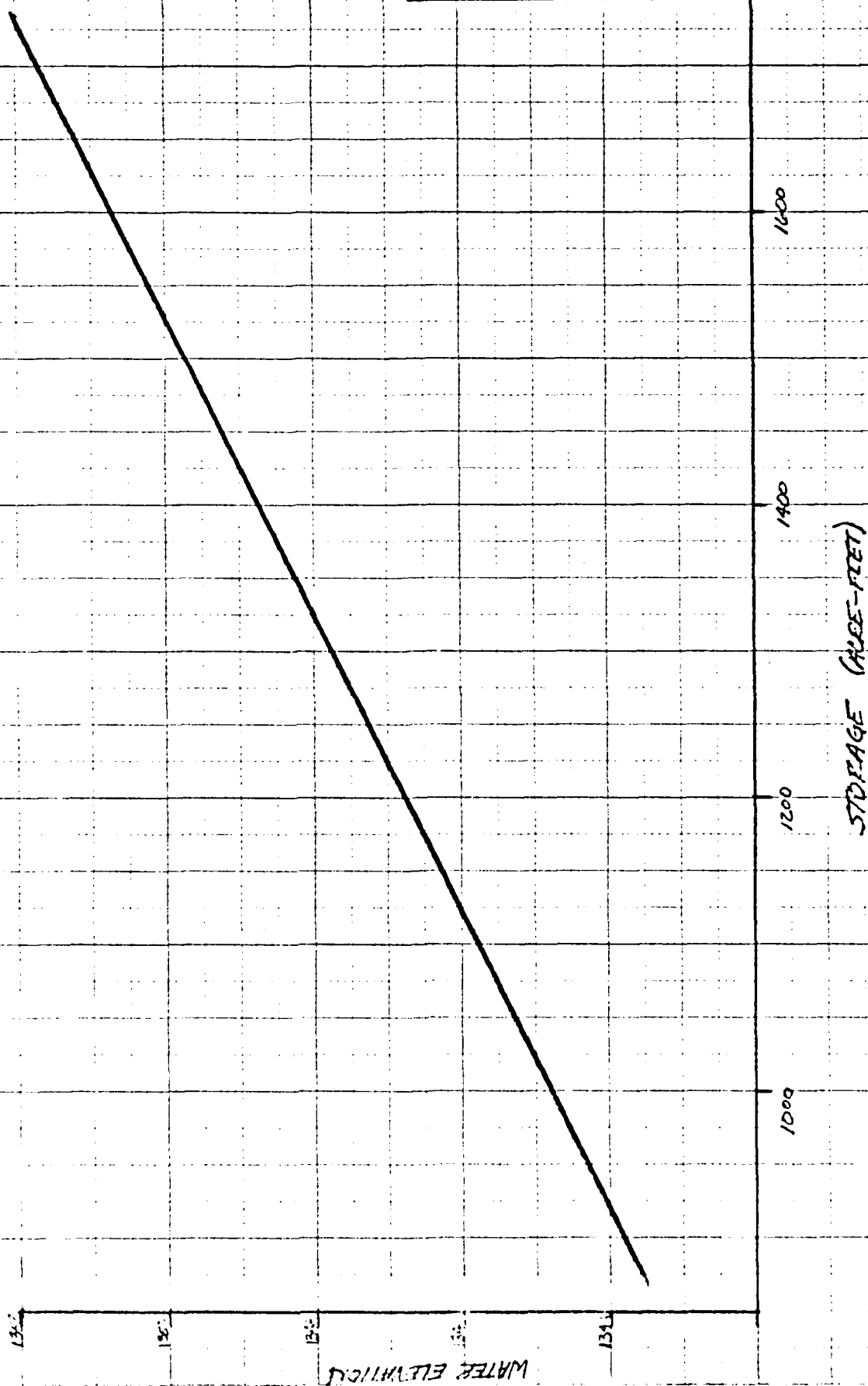
$$\underline{T_p} = 2.2 \left(\frac{L L_c}{151} \right)^{.37} = 2.2 \left[\frac{2.84(.6)(2.84)}{666.5} \right]^{.37} = \underline{1.18}$$

POND STORAGE

ASSUME STORAGE INCREASES BY 102 AC-FT
PER FOOT OF RISE

WSEL	STORAGE (AC-FT)
1344	918
1345	1020
1346	1122
1347	1224
1348	1326
1349	1428
1350	1530
1351	1632
1352	1734

STAGE VS. STORAGE



DUFRESNE-HENRY ENGINEERING CORPORATION

BY W.A.L.
DATE 3-28-79

SUBJECT WOODWARD RESERVOIR
DISCHARGE CALCULATIONS

SHEET NO. 3 OF 33
JOB NO. 04-0090

OR 2X2 CONCRETE LOW LEVEL OUTLET - ORIFICE FLOW

$$Q = CA\sqrt{2gH}$$

ASSUME $C = .73$

FOR SPILLWAY

$$Q = CLH^{3/2}$$

$$L = 13.9'$$

WEIR FLOW

ASSUME $C = 2.6$ WEIR FLOW

ORIFICE FLOW

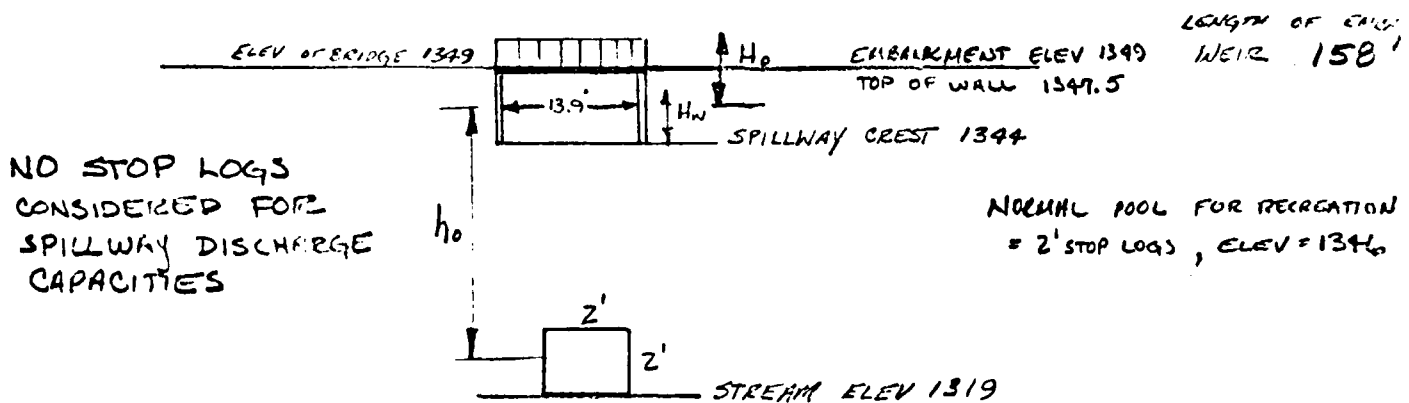
$$Q = CA\sqrt{2gH}$$

$C = .6$ ORIFICE FLOW

FOR OVERBANK

$$Q = CAH^{1/2}$$

ASSUME $C = 2.5$

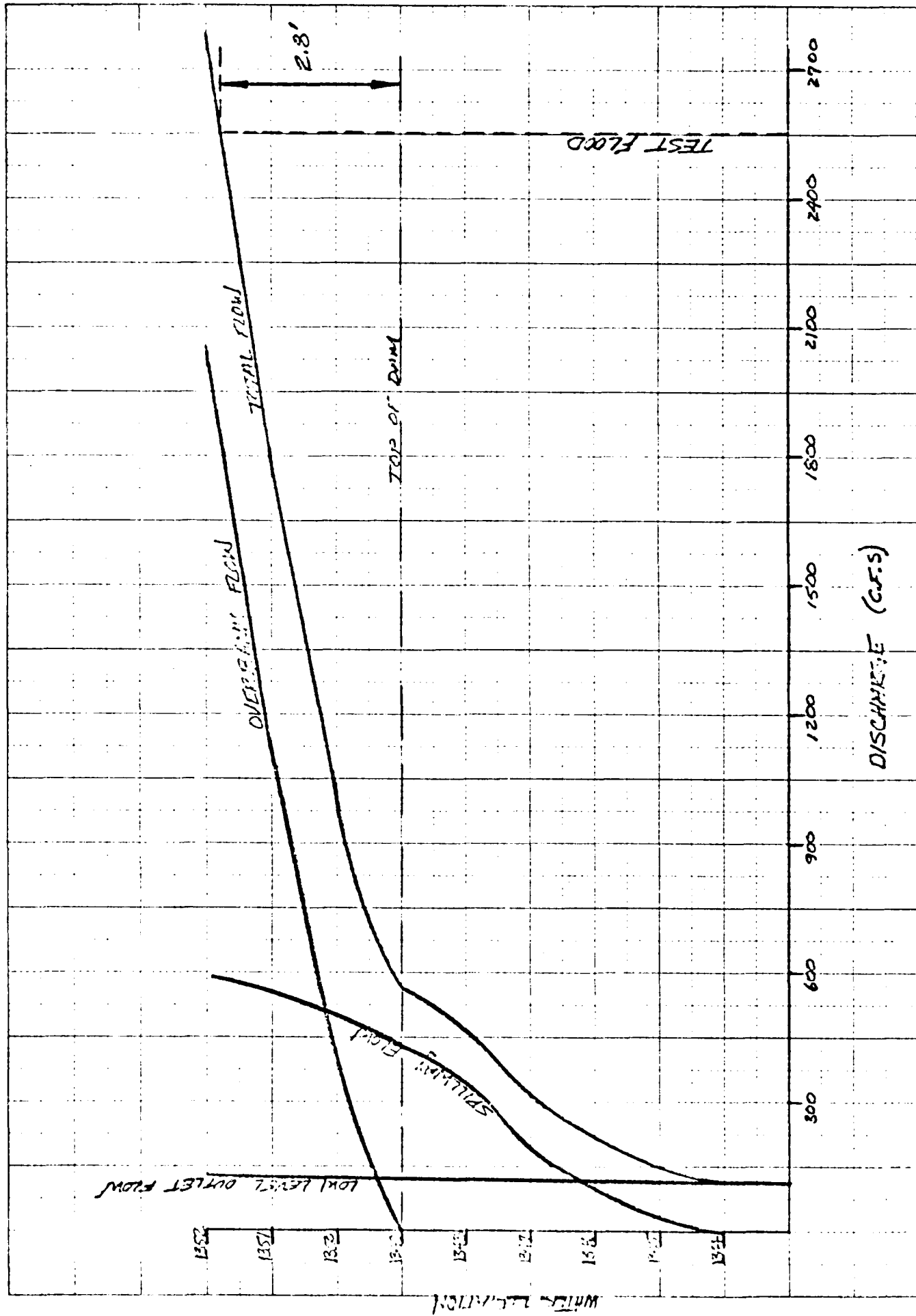


ELEV	$h_{ORIFICE}$	$Q_{ORIFICE}$	H_{W1}	H_{W2}	$Q_{SPILLWAY}$	$H_{OVERBANK}$	$Q_{OVERBANK}$	Q_{TOTAL}
1344	24.0	115	0	0	0	0	0	115
1345	25.0	117	1	1	36	0	0	153
1346	26.0	119	2	2	102	0	0	221
1347	27.0	122	3	3	188	0	0	310
1348	28.0	124	WEIR FLOW	2.25	351	0	0	475
1349	29.0	126	ORIFICE FLOW	3.49	420	0	0	564
1350	30.0	128		4.49	496	1	395	1019
1351	31.0	130		5.49	549	2	1117	1796
1352	32.0	133		6.49	597	3	2052	2782
AREA 4 SQ FT			AREA 3.5 X 13.9 = 48.65					
1347.5	27.5	123	3.5	3.5	237	0	0	360

CAPACITY WITHOUT OVERBANKING: $126 + 438 \Rightarrow 564$

CAPACITY ELEV 1351.0

CAPACITY ELEV 1351.0



DUFRESNE-HENRY ENGINEERING CORPORATION

Y.W.A.L.
DATE 3-20-79

SUBJECT WOODWARD RESERVOIR
DRAINAGE AREA - CLASSIFICATION

SHEET NO. 1 OF 33
JOB NO. 04-0090

DRAINAGE AREA

PLANIMETER READING — 20.01

SCALE 1: 24,000
FACTOR .14348 sq mi / sq in

$$DA. = (20.01)(.14348) = \underline{\underline{2.87 \text{ SQ MI}}}$$

POND SURFACE AREA

SCALE 1: 24,000
FACTOR .14348 sq mi / sq in
640 ac / sq mi

PLANIMETER READING — 1.10

$$(1.10)(.14348)(640) = \underline{\underline{101 \text{ ACRES}}}$$

VOLUME

ESTIMATED IN 1952 AS 40,000,000 CU FT \approx 918 AC-FT

CLASSIFICATION

SIZE

HEIGHT 28.5'
STORAGE 918 AC-FT

AT TOP OF DAM STORAGE 1428 AC-FT \Rightarrow INTERMEDIATE

HARVEST

SEVERAL THOUSAND DOWNSIDE
ABOUT 1 MILE

SIGNIFICANT

STATION 1

500.	1000.	1500.	2000.	2500.	3000.	3500.	4000.	4500.	5000.	6.	8.
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*****										*****										*****													
HYDROGRAPH ROUTING																																	
RESERVOIR ROUTING FOR DOWNWARD RESERVOIR																																	
ESTAO		ICOMP		IECON		ITAPE		JPLT		JPRY		ISAME																					
1		1		0		0		0		0		0		1																			
ROUTING DATA																																	
CLCSS		CLCSS		AVG		IRIS		ISAME																									
0.0		0.0		0.0		1		0																									
NSTPS		NSTDL		LAG		AMSK		X		YSK		STCRA																					
1		0		C		0.0		0.0		0.0		-1.																					
STORAGE#		918.		1020.		1122.		1224.		1326.		1428.		1530.		1632.		1734.															
OUTFLOW#		115.		193.		221.		310.		425.		566.		901.		1005.		2023.															
		TIME		ECP		SPCR		AVG		IN		ECP		OUT																			
		1 0 10				585.		3.		3.				115.																			
		1 0 20				918.		3.		3.				184.																			
		1 0 30				918.		3.		3.				184.																			
		1 0 40				915.		2.		2.				114.																			
		1 0 50				913.		2.		2.				113.																			
		1 0 60				912.		2.		2.				113.																			
		1 1 10				910.		2.		2.				112.																			
		1 1 20				909.		2.		2.				112.																			
		1 1 30				907.		2.		2.				112.																			
		1 1 40				906.		2.		2.				110.																			
		1 1 50				904.		2.		2.				110.																			
		1 1 60				903.		2.		2.				109.																			
		1 2 10				901.		2.		2.				109.																			
		1 2 20				900.		2.		2.				109.																			
		1 2 30				898.		2.		2.				108.																			
		1 2 40				897.		2.		2.				107.																			
		1 2 50				896.		1.		1.				107.																			
		1 2 60				894.		1.		1.				106.																			
		1 3 10				893.		1.		1.				106.																			
		1 3 20				891.		1.		1.				105.																			
		1 3 30				890.		1.		1.				104.																			
		1 3 40				888.		1.		1.				104.																			
		1 3 50				887.		1.		1.				103.																			
		1 3 60				886.		1.		1.				103.																			
		1 4 10				884.		1.		1.				102.																			
		1 4 20				883.		1.		1.				102.																			
		1 4 30				881.		1.		1.				101.																			
		1 4 40				880.		1.		1.				101.																			
		1 4 50				879.		1.		1.				100.																			
		1 4 60				877.		1.		1.				100.																			
		1 5 10				876.		1.		1.				99.																			
		1 5 20				875.		1.		1.				99.																			
		1 5 30				873.		1.		1.				98.																			
		1 5 40				872.		1.		1.				98.																			
		1 5 50				870.		1.		1.				97.																			
		1 5 60				869.		1.		1.				97.																			
		1 6 10				868.		1.		1.				96.																			
		1 6 20				867.		1.		1.				96.																			
		1 6 30				865.		10.		10.				95.																			
		1 6 40				864.		21.		21.				95.																			
		1 6 50				864.		36.		36.				95.																			

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1 11 00	1445.	2871.	4541.
1 11 10	1727.	2652.	2554.
1 11 20	1725.	2462.	2543.
1 11 30	1722.	2266.	2510.
1 11 40	1716.	2059.	2457.
1 11 50	1708.	1837.	2383.
1 11 00	1698.	1602.	2293.
1 11 10	1686.	1362.	2179.
1 11 20	1672.	1129.	2054.
1 11 30	1657.	914.	1918.
1 11 40	1642.	733.	1777.
1 11 50	1627.	565.	1644.
1 11 00	1611.	401.	1510.
1 12 10	1597.	453.	1437.
1 12 20	1584.	435.	1364.
1 12 30	1572.	418.	1258.
1 12 40	1561.	401.	1178.
1 12 50	1550.	386.	1104.
1 12 00	1540.	370.	1035.
1 12 10	1532.	356.	972.
1 12 20	1523.	341.	904.
1 12 30	1515.	328.	803.
1 12 40	1507.	315.	672.
1 12 50	1499.	302.	604.
1 12 00	1492.	290.	513.
1 12 10	1485.	276.	454.
1 12 20	1478.	268.	378.
1 12 30	1471.	257.	332.
1 12 40	1465.	243.	307.
1 12 50	1456.	237.	262.
1 12 00	1452.	228.	254.
1 12 10	1446.	219.	216.
1 12 20	1441.	210.	211.
1 12 30	1435.	202.	192.
1 12 40	1430.	194.	171.
1 12 50	1425.	186.	161.
1 12 00	1419.	178.	156.

SUM

77585.

CPS	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
INCHES	2554.	1621.	539.	539.	77585.
AC-FT		5.25	6.99	6.99	6.99
		804.	1009.	1009.	1009.

1 0 00	883.	37.	95.
1 7 10	883.	76.	96.
1 7 20	883.	98.	96.
1 7 30	883.	118.	95.
1 7 40	884.	136.	95.
1 7 50	884.	150.	95.
1 7 60	885.	161.	95.
1 8 10	886.	170.	96.
1 8 20	886.	177.	96.
1 8 30	889.	183.	97.
1 8 40	870.	187.	97.
1 8 50	871.	191.	98.
1 8 60	873.	194.	98.
1 9 10	874.	196.	99.
1 9 20	875.	197.	99.
1 9 30	877.	198.	100.
1 9 40	878.	200.	100.
1 9 50	879.	201.	101.
1 9 60	881.	201.	101.
1 10 10	882.	202.	102.
1 10 20	884.	202.	102.
1 10 30	885.	203.	103.
1 10 40	886.	203.	103.
1 10 50	888.	203.	104.
1 10 60	889.	203.	104.
1 11 10	890.	203.	105.
1 11 20	892.	203.	105.
1 11 30	893.	203.	106.
1 11 40	894.	203.	106.
1 11 50	896.	203.	107.
1 11 60	897.	203.	107.
1 12 10	898.	207.	108.
1 12 20	900.	211.	108.
1 12 30	902.	212.	109.
1 12 40	906.	217.	110.
1 12 50	910.	218.	112.
1 12 60	917.	225.	115.
1 13 10	925.	234.	118.
1 13 20	936.	242.	122.
1 13 30	949.	248.	126.
1 13 40	963.	251.	132.
1 13 50	980.	257.	138.
1 13 60	997.	262.	145.
1 14 10	1016.	265.	152.
1 14 20	1037.	267.	164.
1 14 30	1058.	271.	178.
1 14 40	1080.	273.	193.
1 14 50	1103.	276.	209.
1 14 60	1128.	277.	228.
1 15 10	1153.	278.	248.
1 15 20	1180.	279.	271.
1 15 30	1208.	280.	297.
1 15 40	1242.	280.	338.
1 15 50	1278.	302.	398.
1 15 60	1319.	363.	464.
1 16 10	1366.	386.	510.
1 16 20	1417.	426.	555.
1 16 30	1471.	458.	733.
1 16 40	1525.	472.	940.
1 16 50	1574.	486.	1273.
1 16 60	1617.	498.	1576.
1 17 10	1652.	524.	1807.
1 17 20	1679.	566.	2117.
1 17 30	1699.	617.	2298.
1 17 40	1712.	636.	2422.
1 17 50	1721.	675.	2500.

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STATION 1

INFL0=81<, OUTFL0=80< AND OBSERVED FLOW=80<

[illegible]

RUNOFF SUMMARY, AVERAGE FLOW

HYDROGRAPH AT		PEAK	6-HOUR	24-HOUR	72-HOUR	AREA
ROUTED TO	1	4732.	2625.	790.	790.	2.87
	A	2554.	1421.	539.	539.	2.87

[illegible]

DUFRESNE-HENRY ENGINEERING CORPORATION

BY W. A. LEONARD

DATE 4-4-79

SUBJECT HOWARD RESERVOIR

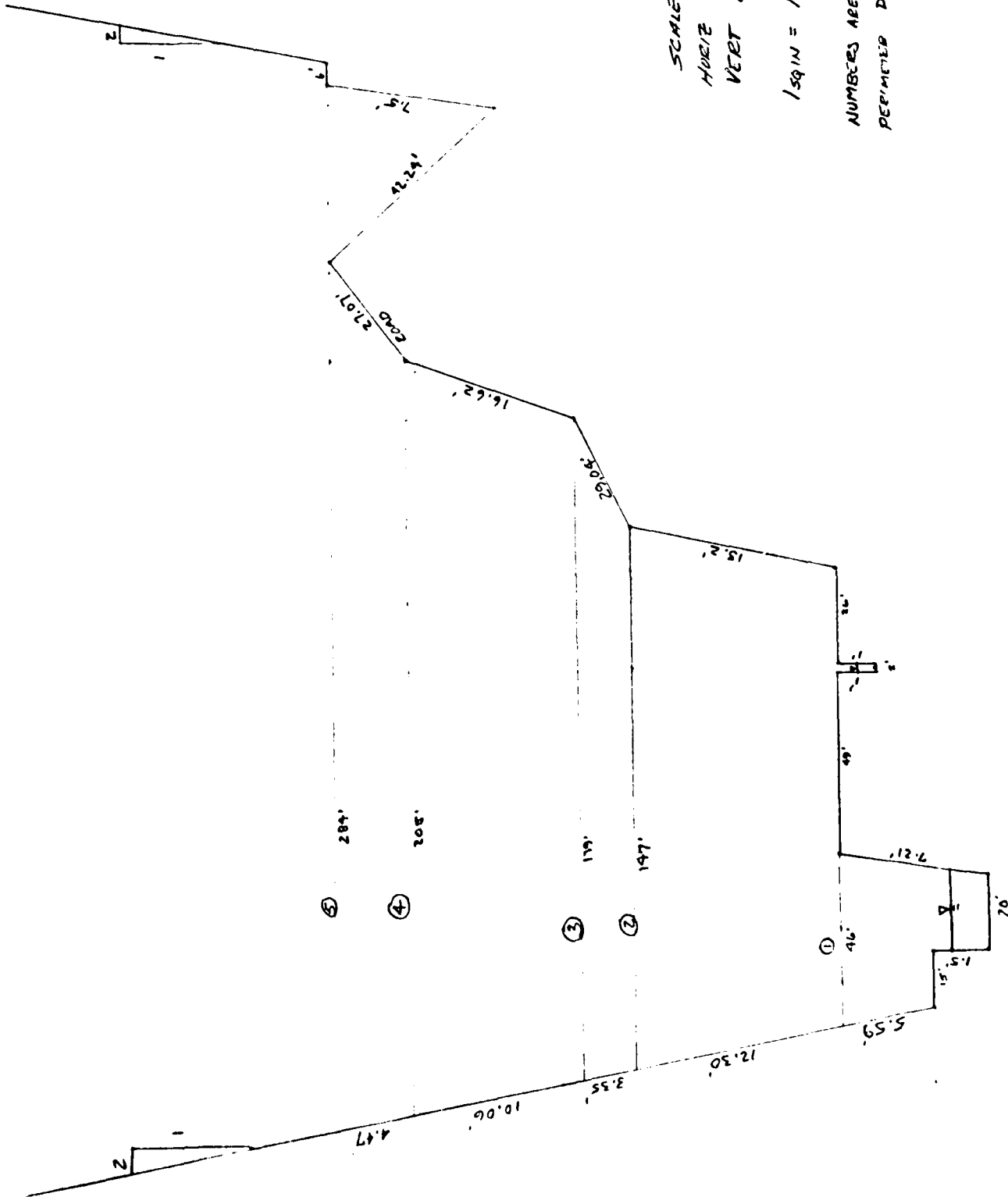
X-SECT "Z" 1,000' DOWNSTREAM

SHEET NO. 28 OF 33

JOB NO. 04-0090

SCALE
HORIZ 1" = 40'
VERT 1" = 4'
1 sq in = 160 sq ft

NUMBERS ARE WETTED
PERIMETER DISTANCES



DUFRESNE-HENRY ENGINEERING CORPORATION

W. A. LEONARD
DATE 4-4-79

SUBJECT HLOODWARD RESERVOIR
X-SECT #1 CALS (CONT.)

SHEET NO. 27 OF 33
JOB NO. 09-0090

$$A = 8.91 (80) = 712.80 \text{ FT}^2$$

$$NP = 69.43 + 3.61 + 30 + 28.18 + 4.53 + 2.83 = 138.58$$

$$Q_4 = \frac{1.486}{.05} (712.8) \left[\frac{712.8}{138.58} \right]^{2/3} (.03)^{1/2} = \underline{\underline{10,993 \text{ CFS}}}$$

5:

$$A = 12.15 (80) = 972 \text{ FT}^2$$

$$NP = 138.58 + 3.61 + 2.83 = 145.02$$

$$Q_5 = \frac{1.486}{.05} (972) \left[\frac{972}{145.02} \right]^{2/3} (.03)^{1/2} = \underline{\underline{17,900 \text{ CFS}}}$$

WITH DAM FAILURE WITH WSEL @ SPILLWAY (7,986 CFS)
WATER WOULD BE APPROX 1' ABOVE ROAD

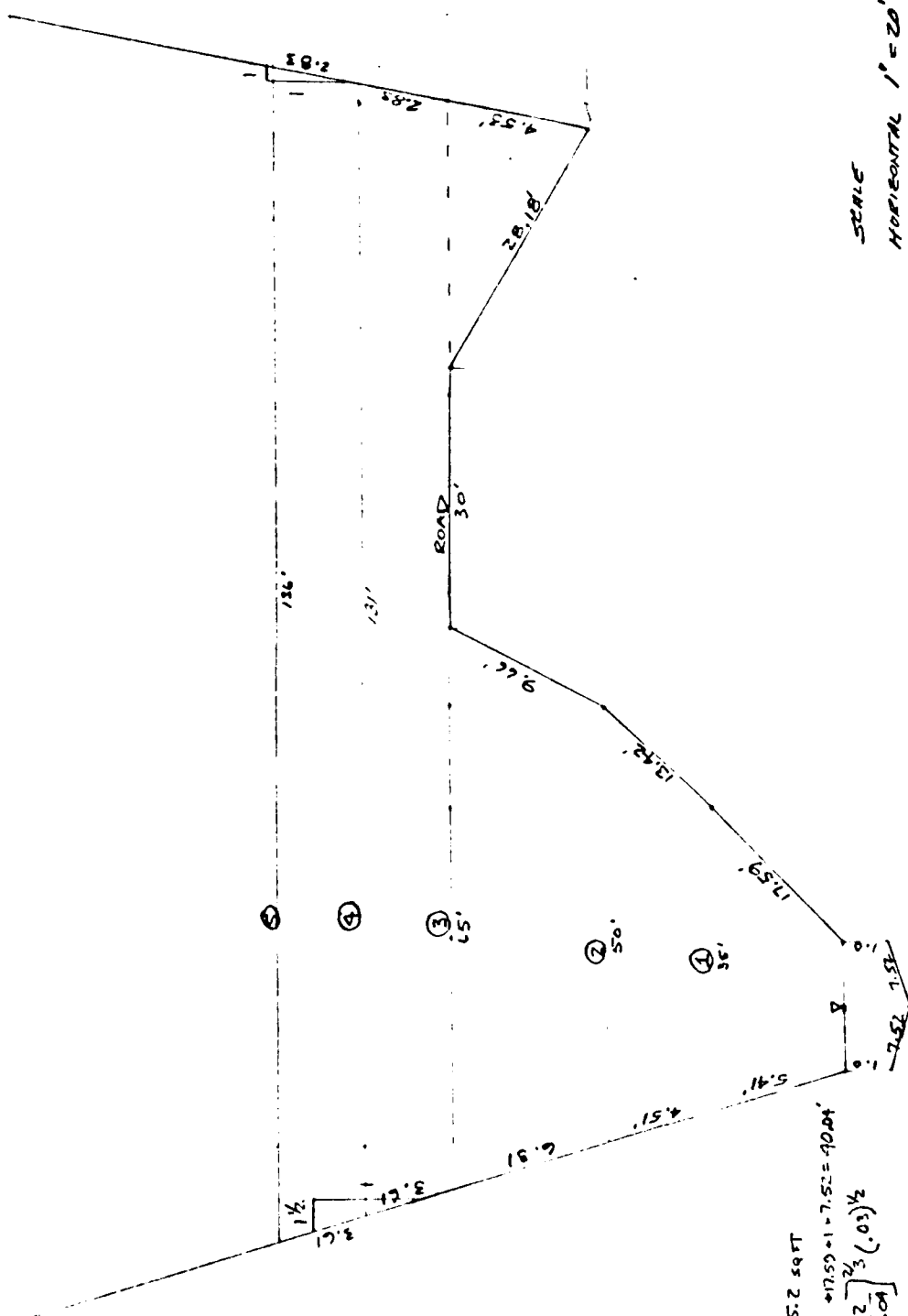
WITH DAM FAILURE WITH WSEL @ TOP OF DAM (10,498 CFS)
WATER WOULD BE 2' ABOVE ROAD

DUFRESNE-HENRY ENGINEERING CORPORATION

BY W.A. LEONARD
DATE 9-4-79

SUBJECT KLOONING RESERVOIR
CROSS-SECTION #1 1200' DOWNSTREAM
CULVERT JUST DOWNSTREAM

SHEET NO. 26 OF 32
JOB NO. 04-0090



SCALE
HORIZONTAL 1" = 20'
VERTICAL 1" = 4'

159 IN = 80.54 FT

NUMBERS ARE METED
PERIMETER DISTANCES

$$Q = \frac{1.486}{N} A R^{2/3} S^{1/2}$$

ASSUME $S = .03$
 $N = .05$

$$A = 1.19(80) = 95.2 \text{ sq ft}$$

$$NP = 7.62(10.64) + 17.52(17.52) = 4004'$$

$$Q = \frac{1.486}{.05} \left[\frac{95.2}{40.04} \right]^{2/3} (.03)^{1/2}$$

$$Q_1 = 876 \text{ cfs}$$

$$A = (80)(80) = 209.8 \text{ sq ft}$$

$$NP = 1.52(10.64) + 4.51 + 17.52(17.52) + 10.64(7.52) = 57.97'$$

$$Q = \frac{1.486}{.05} \left[\frac{209.8}{57.97} \right]^{2/3} (.03)^{1/2} = 2456 \text{ cfs}$$

$$A = 5(80) = 401.6$$

$$NP = 7.62(10.64) + 4.51 + 17.52(17.52) + 10.64(7.52) = 69.43'$$

$$Q_1 = \frac{1.486}{.05} \left[\frac{401.6}{69.43} \right]^{2/3} (.03)^{1/2} = 6701 \text{ cfs}$$

DUFRESNE-HENRY ENGINEERING CORPORATION

L.
3-29-79

SUBJECT WOODWARD RESERVOIR
DAM FAILURE ANALYSIS

SHEET NO. 25 OF 33
JOB NO. 04-0090

1 FAILURE WSEL @ SPILLWAY CREST ELEV 1344

$$Q = 8/27 Wb \sqrt{g} Y_0^{3/2}$$

$$Q = 8/27 (.4)(95) \sqrt{32.2} (25)^{3/2} = \underline{\underline{7,986 \text{ C.F.S.}}}$$

1 FAILURE WSEL @ TOE OF ROADWAY ELEV 1349

$$Q = 8/27 Wb \sqrt{g} Y_0^{3/2}$$

$$Q = 8/27 (.4)(95) \sqrt{32.2} (30)^{3/2} = \underline{\underline{10,498 \text{ C.F.S.}}}$$

DISCHARGE CHANNEL SLOPE

$$\frac{1200 - 1100}{1900} = .05 = 5\%$$

DUE TO THE STEEP SLOPE OF THE DISCHARGE CHANNEL
THE "RULE OF THUMB" ROUTING IS NOT APPLICABLE.
THEREFORE USE THE PEAK FAILURE OUTFLOW

DUFRESNE-HENRY ENGINEERING CORPORATION

L. LEONARD
4-4-79

SUBJECT WOODWARD RESERVOIR
X-SECT #2 FLOW CALCS

SHEET NO. 29 OF 33
JOB NO. 04-0090

ASSUME $n = .05$, $s = .03$

$$A = 0.88(160) = 140.8 \text{ ft}^2$$

$$WP = 20 + 1.5 + 15 + 5.53 + 7.21 = 49.3'$$

$$Q_1 = \frac{1.486}{.05} (140.8) \left[\frac{140.8}{49.3} \right]^{2/3} (.03)^{1/2} = \underline{1464 \text{ C.F.S.}}$$

$$A = 5.58(160) = 892.8 \text{ ft}^2$$

$$WP = 49.3 + 12.3 + 49 + 1.2 + 1 + 26 + 13.2 = 153.8'$$

$$Q_2 = \frac{1.486}{.05} (892.8) \left[\frac{892.8}{153.8} \right]^{2/3} (.03)^{1/2} = \underline{14932 \text{ C.F.S.}}$$

$$A = 7.13(160) = 1140.8 \text{ ft}^2$$

$$WP = 153.8 + 3.35 + 29.04 = 186.19'$$

$$Q_3 = \frac{1.486}{.05} (1140.8) \left[\frac{1140.8}{186.19} \right]^{2/3} (.03)^{1/2} = \underline{19,782 \text{ C.F.S.}}$$

∴ CHANNEL WOULD EASILY HOLD WATERS FROM
A DAM FAILURE AT THIS POINT

NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS
WOODWARD RESERVOIR DA. (U) CORPS OF ENGINEERS WALTHAM
MA NEW ENGLAND DIV MAY 79

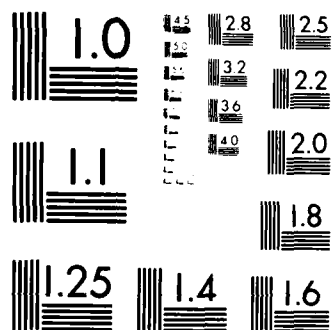
2/2

F/G 13/13

NL

END

7. 100 mg/kg



MICROCOPY RESOLUTION TEST CHART

U.S. NATIONAL BUREAU OF STANDARDS - 1963-A

DUFRESNE-HENRY ENGINEERING CORPORATION

BY W.A. LEONARD
DATE 4-4-79

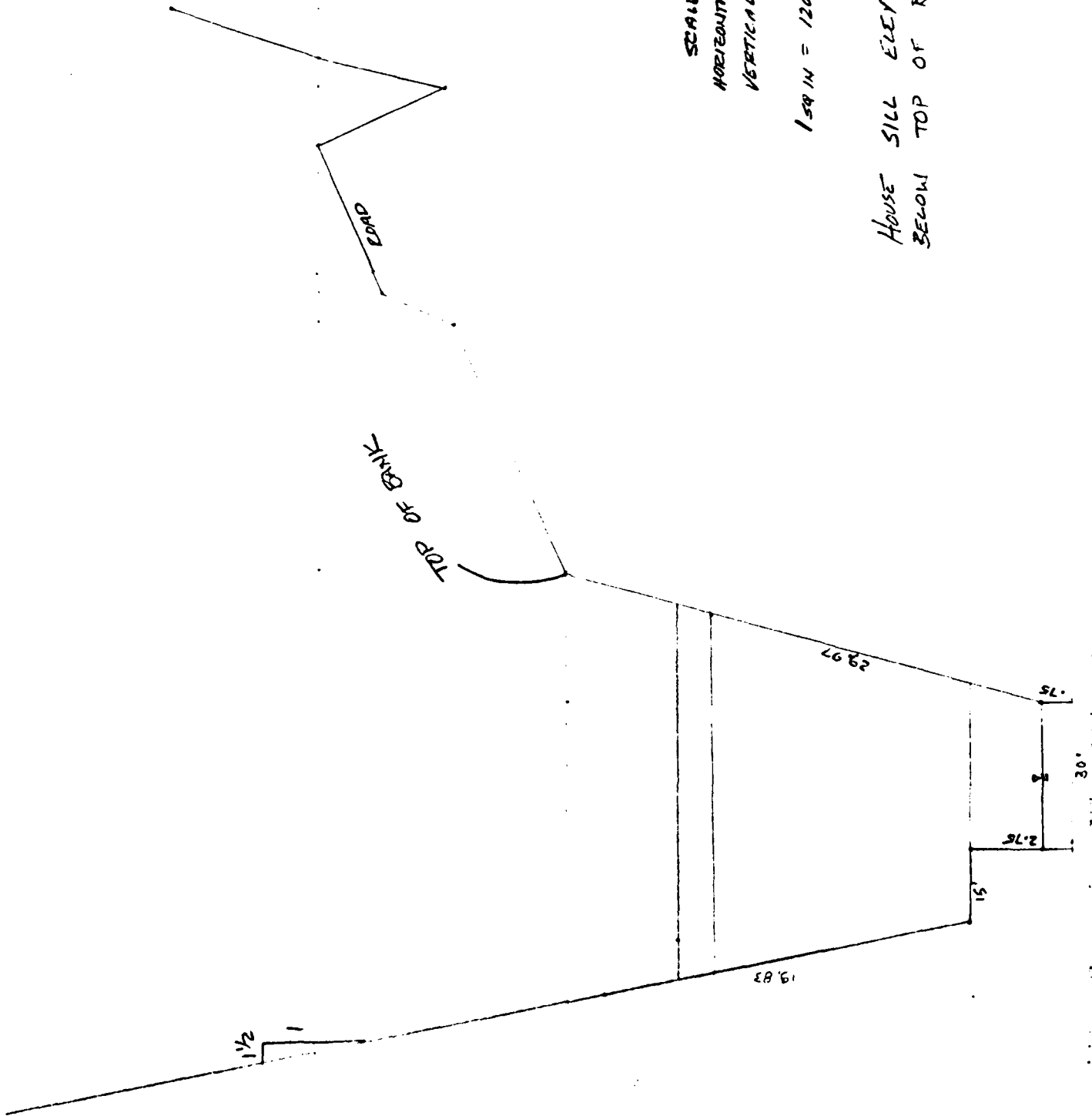
SUBJECT WOODWARD RESERVOIR
X-SECT # 3 5200'

SHEET NO. 30 OF 33
JOB NO. 04-0090

SCALE
HORIZONTAL $1"=30'$
VERTICAL $1"=4'$

1 sq in = 120 sq ft

HOUSE SILL ELEV 3'
BELOW TOP OF BANK



DUFRESNE-HENRY ENGINEERING CORPORATION

W.A. LEONARD
DATE 4-4-79

SUBJECT WOODWARD RESERVOIR
X-SECT #2 FLOW CALCS

SHEET NO. 29 OF 33
JOB NO. 04-0090

ASSUME $n = .05$, $s = .03$

C₁: $A = 0.88(160) = 140.8 \text{ ft}^2$
 $WP = 20 + 1.5 + 15 + 5.53 + 7.21 = 49.3'$
 $Q_1 = \frac{1.486}{.05} (140.8) \left[\frac{140.8}{49.3} \right]^{2/3} (.03)^{1/2} = 1464 \text{ C.F.S.}$

C₂: $A = 5.58(160) = 892.8 \text{ ft}^2$
 $WP = 49.3 + 12.3 + 49 + 1.2 + 1 + 26 + 13.2 = 153.8'$
 $Q_2 = \frac{1.486}{.05} (892.8) \left[\frac{892.8}{153.8} \right]^{2/3} (.03)^{1/2} = 14,932 \text{ C.F.S.}$

C₃: $A = 7.13(160) = 1140.8 \text{ ft}^2$
 $WP = 153.8 + 3.35 + 29.04 = 186.19'$
 $Q_3 = \frac{1.486}{.05} (1140.8) \left[\frac{1140.8}{186.19} \right]^{2/3} (.03)^{1/2} = 19,782 \text{ C.F.S.}$

∴ CHANNEL WOULD EASILY HOLD WATERS FROM
A DAM FAILURE AT THIS POINT.

DUFRESNE-HENRY ENGINEERING CORPORATION

BY W.A. LEONARD

SUBJECT KLOODVIARD RESERVOIR

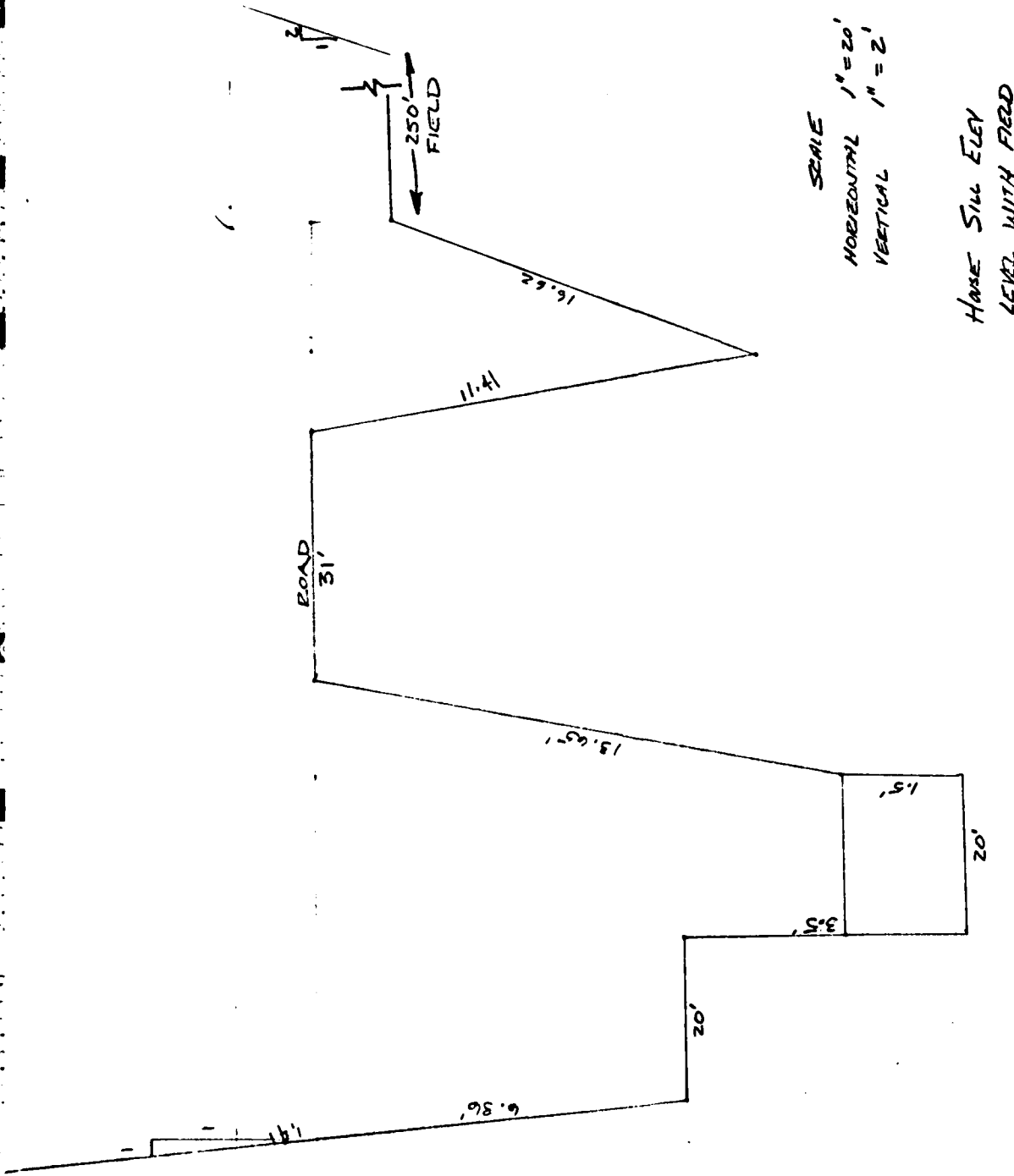
SHEET NO. 32 OF 33

DATE 4-4-79

X-SECT #4

6700' DOWNSTREAM

JOB NO. 04-0090



DUFRESNE-HENRY ENGINEERING CORPORATION

F. W. A. LEONARD
DATE 4-4-'19

SUBJECT WOODWARD RESERVOIR
X-SECT #3 FLOW CALCULATIONS

SHEET NO. 31 OF 33
JOB NO. 04-0090

TOP OF BANK :

$$A = 7.12 (120) = 854.4 \text{ FT}^2$$

$$W.P. = 19.83 + 15 + 2.75 + 30 + .75 + 29.97 = 98.3'$$

$$Q = \frac{1.486}{.05} (854.4) \left[\frac{854.4}{98.3} \right]^{2/3} (.03)^{1/2} = \underline{\underline{18,727 \text{ CFS}}}$$

TOP BANK - 3'
(HOUSE SILL ELEV)

$$A = 5.01 (120) = 601.2 \text{ FT}^2$$

$$W.P. = 98.3 - 5.41 - 6.92 = 85.97$$

$$Q = \frac{1.486}{.05} (601.2) \left[\frac{601.2}{85.97} \right]^{2/3} (.03)^{1/2} = \underline{\underline{11,390 \text{ CFS}}}$$

TOP BANK - 4'

$$A = 4.39 (120) = 526.8 \text{ FT}^2$$

$$W.P. = 85.97 - 1.80 - 2.31 = 81.86'$$

$$Q = \frac{1.486}{.05} (526.8) \left[\frac{526.8}{81.86} \right]^{2/3} (.03)^{1/2} = \underline{\underline{9,440 \text{ CFS}}}$$

FOR DAM FAILURE WITH WSEL AT TOP OF DAM (10,498 CFS)
THE HOUSE AT THIS CROSS SECTION WOULD BE UNDERMINED
& DESTROYED AS THE BASEMENT LEVEL IS EXPOSED & SITS
ON THE BROOK BANK.

DUFRESNE-HENRY ENGINEERING CORPORATION

BY W.A. LEONARD
DATE 4-5-79

SUBJECT WOODWARD RESERVOIR
X-SECT # 4 FLOW CALS

SHEET NO. 33 OF 33
JOB NO. 04-0090

C. LEVEL WITH
ROAD

$$A = 7.64(40) = 305.6 \text{ FT}^2$$

$$W.P. = 6.36 + 20 + 3.5 + 20 + 1.5 + 13.65 = 65.01$$

$$Q = \frac{1.486}{.05} (305.6) \left[\frac{305.6}{65.01} \right]^{2/3} (.03)^{1/2} = \underline{\underline{4437 \text{ CFS.}}}$$

∴ IF DAM FAILED, WATER WOULD BE ABOVE ROAD AND FLOW INTO ADJACENT FIELD

ASSUME WATER JUST CROSSING ROAD & INTO FIELD

Q:

$$A = (7.64 + 2.00)(40) + 250(1) = 635.6 \text{ FT}^2$$

$$W.P. = 65.01 + 31 + 11.41 + 16.62 + 250 + 2.24 = 376.28 \text{ FT}$$

$$Q = \frac{1.486}{.05} (635.6) \left[\frac{635.6}{376.28} \right]^{2/3} (.03)^{1/2} = \underline{\underline{4649 \text{ CFS}}}$$

ASSUME WATER 1' ABOVE ROAD

$$A = 12.48(40) + 504 = 1003.2 \text{ FT}^2$$

$$W.P. = 376.28 + 2.24 + 1.41 = 379.93 \text{ FT}$$

$$Q = \frac{1.486}{.05} (1003.2) \left[\frac{1003.2}{379.93} \right]^{2/3} (.03)^{1/2} = \underline{\underline{9897 \text{ CFS}}}$$

THIS WOULD MEAN 2' OF WATER AROUND HOUSES

PORTION OF FLOW IN CHANNEL WOULD BE

$$A = 9.06(40) = 362.4$$

$$W.P. = 1.41 + 6.36 + 20 + 3.5 + 20 + 1.5 + 13.65 + 1 = 67.42$$

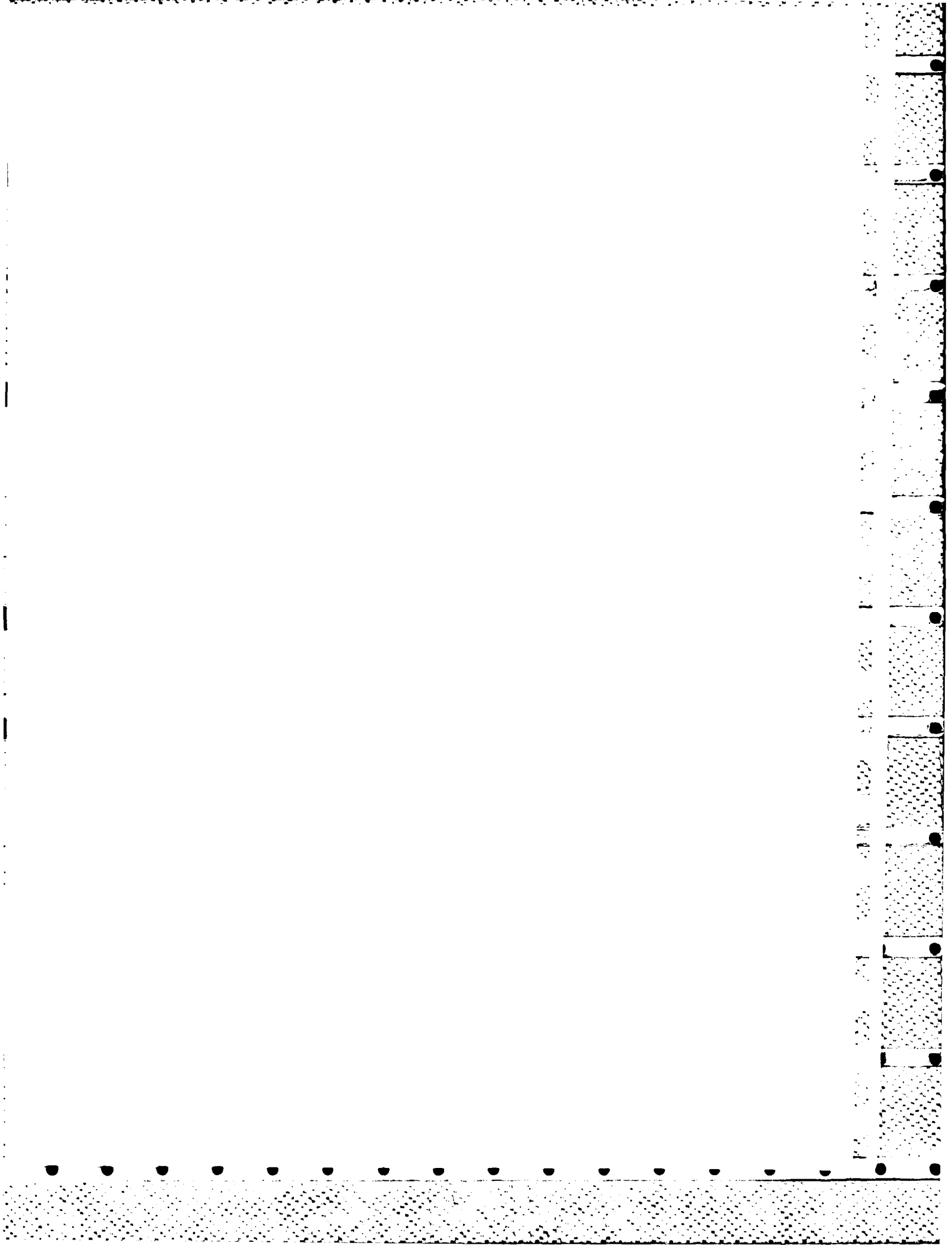
$$Q = \frac{1.486}{.05} (362.4) \left[\frac{362.4}{67.42} \right]^{2/3} (.03)^{1/2} = \underline{\underline{5757 \text{ CFS}}}$$

$$\text{FLOW IN FIELD} = 9897 - 5757 = \underline{\underline{4140 \text{ CFS}}}$$

$$\text{VELOCITY OF WATER IN FIELD} = \frac{4140}{1003.2 - 362.4} = \underline{\underline{6.46 \text{ FPS}}}$$

APPENDIX E

Information as Contained in the National Inventory of Dams



END

FILMED

8-85

DTIC